XXI.—THE HISTORY OF FISH-CULTURE.

A—THE HISTORY OF FISH-CULTURE IN EUROPE FROM ITS EARLIER RECORDS TO 1854.*

BY JULES HAIME.

Fisheries have often been called the agriculture of the waters, as if seas, lakes, and rivers were inexhaustible store-houses of food, where, without fear of ever impoverishing them, man might continue to take and destroy forever, bounded only by his wants and desires. This definition is false, because founded on a false view of the case. Fishery is not the agriculture of the waters; it is only the harvesting. The waters are a source of production extremely powerful, but by no means infinite; and that the harvest may be always certain and abundant, it should be prepared by regular sowing, if it is true, according to the expression of M. de Quatrefages, that fish may be multiplied by sowing in the same manner as grain.

This would appear unnecessary pains, if we were to consider only the very great fecundity of almost all the aquatic tribes. A perch of moderate size contains 28,320 eggs, and a herring 36,960.

Thomas Harmer† and C. F. Lund‡ have obtained, by untiring researches, still higher numbers from other species, *e. g.*, 80,388 and 272,160 for the pike; 100,360 for the sole; 71,820 and 113,840 for the roach; 137,800 for the bream; 383,250 for the tench; 546,680 for the mackerel. A carp weighing 3 kilograms (66 pounds) *contained*, according to Petit, 342,140 eggs. A flounder has given the enormous figure of 1,357,400. There have been counted in a sturgeon as many as 7,635,200, and Leeuwenhoek has found 9,344,000 in a codfish. Finally, M. Valenciennes§ has just

*In the Revue des Deux Mondes, June 15, 1854, Paris, was published an article on Pisciculture, by Jules Haime, a translation of which, by Mr. Gamaliel Bradford, appeared in the Report of commissioners appointed under resolve of 1856, chapter 58, [of the legislature of Massachusetts,] concerning the artificial propagation of fish, with other documents, Boston, 1857.

As the most complete paper published on this portion of the history of fish-culture, and as a suitable introduction to the account of methods in use in the United States, it is here reproduced.—S. F. BAIRD.

† Philosophical Transactions Royal Society of London, vol lvii, p. 280, 1768.

‡ Memoirs of the Swedish Royal Association of Sciences, vol. xxiii, German ed., p. 192, 1761.

§ Valenciennes and Frémy. Researches on the composition of eggs in the series of animals. Academy of sciences, March 20, 1854.

calculated that there are 9,000,000 in a turbot of 50 centimeters, (19½ inches,) and as many as 13,000,000 in a thick-lipped mullet.

If only the tenth part of the germs inclosed in the body of each fish arrived at maturity, there must be little to fear from the devastation of our coasts, or the depopulation of our fresh waters; but numerous causes of destruction tend to reduce considerably the multiplication thus richly provided for. These arise partly from natural causes, but in great part also from the act of man. We are to point them all out, if possible, and weigh them successively before discussing the means of preventing their action, which will form the chief object of this article.

In the first place, we must not forget that, in the general harmony of nature, as Mr. Milne-Edwards has justly remarked, the productiveness of animals is regulated with a view not only to the dangers to which the young are exposed before ariving at the age of reproduction themselves, but also to the uncertainty of fecundation of the eggs. It is well known that the immense majority of fishes are oviparous, and that the fecundation is effected by the operation of the male element upon the female element separate from the body of the animals, and in the midst of the waters where they live. This action is the condition necessary to the development of the embryo, and all the eggs which have not experienced the contact with the animalcules of the milt change and soon decay. Now, it is never the case that all the spawn receives this action, and from this cause alone a portion, more or less considerable, is always lost. The portion which remains is in turn exposed to a host of pernicious influences. It may be left dry by a decline in the level of the water, or spoiled by the slimy substances which a rise of the water always causes and carries with it. The spawn has also numerous enemies; many fish devour it, many crustacea, many insects attack it in like manner; it may be carried off by sea-weeds and byssus, and almost all aquatic birds are very fond of it.

All these chances of mortality and destruction prevent the fish from increasing as fast as the great number of eggs would at first lead us to suppose, but they are still in a measure subject to the laws of the animal creation, and would seldom suffice for the depopulation of the waters, unless supported by causes of another nature. Among these should be mentioned, first of all, the inadequacy of the legislation on the fisheries, and the violation with impunity of all the protecting ordinances which it has provided.

At the end of the last century Duhamel pointed out the depredations of the fishermen, who cast their lines, with impunity, at all seasons of the year, and daily suffer numbers of fishes, too small to be sold, to perish upon the banks. He saw, with natural indignation, the inhabitants of the coasts fill baskets with the spawn to manure their land or feed their swine. This culpable improvidence has still further increased, and we can almost say that, at the present time, all injuries are authorized and all abuses are practiced without limit. In vain the bestgrounded complaints are raised against the poachers upon fisheries: the devastations have continued on all sides.

The necessity has been felt, however, for a long time, of taking repressive measures against the destruction of spawn, and the historians of fishery have collected numerous ordinances, which have been successively issued with this view at different times and in different countries. Without citing them all, it will be sufficient to recall those which have had the greatest influence upon the legislation of the present time. In the year 966, Ethelred II, king of the Anglo-Saxons, interdicted the sale of young fishes. Malcolm II, in 1030, fixed the time of the year when the salmon-fishery should be permitted. Several other kings of Scotland have confirmed these decrees. Under Robert I, the willows of the bow-nets were to be separated by at least two inches of interval, to leave a passage for the young fry. In 1400, Robert III carried severity so far as to punish capitally every person convicted of having taken a salmon in the forbidden season. This cruel law was abolished by James I, but this prince kept up the interdict during the same season, and every infraction still remained the object of severe penalties. The kings of France were at great pains also to insure the free development of the young fishes. A great number of ordinances were issued by them, to determine the nature of the nets of which the use should be permitted, and the length of the fishes which might be sold in the market-places. At lengh, in 1669, Colbert placed upon a new footing the legislation of the coasts and rivers. He prohibited river-fishing during the night and during the spawning-season, under penalty of a fine of twenty livres and a month's imprisonment for the first offense, of a fine double in amount and two months' imprisonment for the second, and of the pillory and the scourge for the third. The only exceptions were in the fisheries of salmon, shad, and lampreys. Colbert also prohibited the placing of basket-work at the end of the drag-nets during the spawning-season, under penalty of twenty livres fine; and after having determined the kinds of snares to be forbidden, he directed that the fishermen should return to the streams the trouts, carps, barbels, breams, and millers which they should take having less than six inches between the eye and the tail, and the tenches, perches, and mullets having less than five inches, under a penalty of one hundred livres fine.

The legislation which governs us at present is based upon the previous dispositions; unfortunately, it has disregarded the information offered by natural history, and thus but imperfectly attains the object proposed. The regulations relative to marine-fishing permit, for example, the taking of a given fish on shores where it has never been found, and give, for the limit of the crustacea, indications contrary to the most simple common sense. The code of river-fishing, which principally interests us here, is no better protected against criticism. The ordinance of November 15, 1830, supplementary to that of April 15, 1829, leaves to the prefect of each department the care of determining, with the advice of the general council, and after having consulted the foresters, the times, seasons, and hours when fishing shall be prohibited in the rivers and water-courses. Now, how many times must the prefects, little skilled in natural science or ill-advised by those whose duty it is to enlighten them, have committed errors like those of Colbert, when he interdicted trout-fishing from the first of February to the middle of March, that is to say, at a time when they had nearly all already finished spawning! The same ordinance prohibits certain specified nets and snares, thus intimating that all others are authorized, and permitting changes of form and name in the first, without rendering them less formidable or destructive. Article 30 of the fishery-code punishes, with a fine of 20 to 50 francs, whoever shall catch, offer for sale, or sell fishes of less than the prescribed size, but it excepts from this provision sales of fish coming from ponds or reservoirs. It will at once be perceived how easy it is, through this exception, to catch and sell fishes of all sizes. Article 24 forbids the placing of any gate, structure, or fishing-establishment whatever, calculated to prevent entirely the passage of fish, but it tacitly authorizes dikes and mill-dams, which produce the same effect.

We will carry criticism no farther. It would be as easy for us to show that no efficacious measures insure the action of the fish-police, and that the law is as badly executed as conceived. This state of things is deplorable, and has, without doubt, powerfully contributed to bring on the decay which has fallen upon the aquatic industry of France.*

Some figures, taken from the archives of the ministry of finance, will show clearly the importance of the evil. The water courses of France have a total length of 197,255 kilometers, (122,500 miles.) Its lakes, reservoirs, and fish-ponds occupy a superficies of 220,000 hectares, (900 square miles.) Now, the rent of all the waters directed by the commissioners of forests, and those of dikes and bridges, yields to the state a revenue of 660,000 francs. The former alone give fishing-privileges in 7,570 kilometers (4,750 miles) of navigable and floating water-courses, producing the annual sum of 521,395 francs; that is, an average of 69 francs to the kilometer. The insignificance of this sum is very striking when compared with what it ought to be, or even with that still furnished by some rivers more favored than others. Thus, the Doubs, in the Jura, is still let out at the rate of 159 francs the kilometer; the Moselle, in the department of La Meurthe, at the rate of 182 francs. For a similar length, the Loire brings in 252 francs in La Loire Infé-

*The evil has been further increased by the encroachments of manufacturing industry, as well as by the processes which they have involved. The mills throw off into the water-courses their acids and salts which have become useless, and the bleachers do the same with their chlorides. The beds of streams have often to be laid dry to execute dragging and cleansing. Finally, steamboats, by their violent movements of the water, raise and cast up the young fishes upon the river-banks, and these are often detained and perish there. These last causes of destruction are still more fatal to the development of the fry than the culpable practices of the poachers.

rieure, (department;) the Sarthe 297 francs in Le Mairie et Loire; and the Loiret 309. La Mayenne produces 339 francs, and the Seine 498. As for the Mairie, it produces the exceptional sum of 1,378 francs. By the side of these figures, more or less satisfactory, many others attest, on the contrary, the extreme scarcity of fish. The Ain, in the Jura, produces only 14 francs to the kilometer; the Dordogne, in the department of La Corrèze, 10 francs; the Isère, 8 francs; the Drôme, 4; and the Durance, 2. Finally, 219 kilometers have been depopulated to that point that they cannot be let at any price.

This marked inequality in the revenues of several rivers, which offer in general similar conditions to the fish, or whose different conditions can be differently improved, seems to indicate that the evil, even where greatest, is not irreparable. The proprietors, injured by the impoverishment of the fisheries, and the government itself more interested than anybody in the products of the rivers, have yet remained a long time inactive under the laws which they are sustaining. The remedy has been decided upon only after the reiterated solicitations of naturalists, who, long since masters of a process of artificial multiplication, have felt that it might be usefully applied to the repopulating of rivers and ponds. The first experiments have given results sufficiently remarkable not to discourage farther attempts. The practical methods have been promptly developed, and scientific researches skillfully conducted have impressed a new character upon pisciculture; that is, the branch of rural economy which is occupied with the improvement of waters. A very general interest is now felt in this important question of the artificial multiplication of fish, which belongs at once to the natural sciences, to agriculture, and to political economy. The result of the experiments which, since the end of the last century, have had for their object the restocking of rivers, already forms a curious chapter of zoological history; and while awaiting its increase by some new pages, it appears to us desirable to reunite its scattered elements.

I.

The first attempts at pisciculture were made by the Chinese and the ancient Romans, and it is probable that they were preceded by their elders in civilization. We have no positive data as to the epoch in which the Chinese commenced these experiments; but everything tends to show that they reach back to the most remote antiquity. We find in the "Histoire générale des voyages," (1748,) in Grosier, in Davis, as M. Chevreul has already pointed out, and in most of the works which treat of Chinese customs, some curious details on the transport of the spawn of fish. According to the missionaries who have visited China, a multitude of salmon, trout, and sturgeons mount into the rivers of Kiang-si and into the ditches which are dug in the middle of the fields to preserve the water necessary to the production of rice. They deposit their eggs there, and the young, which are soon hatched, are a source of considerable profit to the riparian proprietors. The Jesuit father John Baptiste Duhalde, is the first French author who has shown* the manner in which this traffic is effected. We give his account, which most historians have copied with alterations: "In the great river Yang-tse-kiang, not far from the city Kieou-king-fou, in the province of Kiang-si, at certain times of the year, are assembled a prodigious number of boats for the purchase there of the eggs of fish. Toward the month of May, the country-people bar the river in various places with mats and hurdles for a length of about nine or ten leagues, leaving only sufficient space for the passage of the boats; the eggs of the fish are stopped by these hurdles. They can distinguish them by the eye, where other persons see nothing in the water; they draw out this water mixed with eggs, and fill several vases with it for sale, which causes, at this season, numbers of merchants to come with their boats to buy it, and transport it into different provinces, taking care to agitate it from time to time. They succeed one another in this operation. The water is sold in measures to all those who have fish-preserves and domestic ponds. After some days there are seen in the impregnated water, as it were, little heaps of fishes' eggs, without its being yet possible to distinguish the species. It is only with time that this appears. The profit is often a hundred fold more than the outlay, as the people live in great part upon fish." To these very simple but successful means of replenishing their ponds, the Chinese are said to have joined others which travelers have only very imperfectly indicated; they assert that when the young fish begins to eat, they give him marsh-lentils mixed with yellow of eggs.

The Romans had nearly similar customs at a very early epoch. "The descendants of Romulus and Remus," says Columella,† "rustics as they were, had much at heart the procuring upon their farms a sort of abundance in every thing like that which reigns among the inhabitants of the city; thus they were not satisfied with stocking with fish the ponds which they had constructed for this purpose, but carried their foresight to the point of filling lakes formed by nature with the spawn of fish which they threw into them. In this way the lakes Velinus and Sabatinus, as well as the Vulsmensis and Ciminus, have, in the end, abundantly furnished, not only cat-fish and gold-fish, but, moreover, all other sorts of fish which are able to live in fresh water." These practices were early abandoned, and it is a matter of surprise, when we consider the strange infatuation of which fish became the object in ancient Italy during the following centuries, that no measures were then taken to insure their reproduction and free development. It is well known that the ancients had a remarkable predilection for this species of food. The principal luxury of the Roman banquets consisted of fish, and the poets

*History of the Chinese Empire, vol. i, p. 35, 1735

†De Re Rustica, book viii, section 16.

speak of sumptuous tables spread with these exclusively. In the period between the taking of Carthage and the reign of Vespasian, this taste became a perfect passion, and for its gratification the senators and patricians, enriched by the spoils of Asia and Africa, incurred the most foolish expense. Thus Licinius Murena, Quintus Hortensius, Lucius Philippus, constructed immense basins, which they filled with the most rare species, and Lucullus, like a new Xerxes, caused a mountain to be pierced to introduce sea-water into his fish-ponds. Varro* relates that Hirrius received twelve millions of sesterces ($675,000) from the numerous buildings which he possessed, and that he employed the entire sum in the care of his fishes. The rich patricians, says the same author, were not satisfied with a single pond; their fish-preserves were divided into compartments, where they kept shut up, apart from each other, fishes of different kinds; they retained a great number of fishermen solely to take care of these animals. They tended their fish as carefully as their own slaves during sickness. It is even added that a naval expedition, commanded by an admiral, had for its object to introduce upon the coast of Tuscany a sort of scar, peculiar to the water of Greece.†

This extravagant fashion, which spread through the various classes of society, and brought on the ruin of entire families, had also the effect of impoverishing the coasts of the Mediterranean. Ismeral complained that time was no longer given to the fish of the Tyrrhenian Sea to come to maturity. The scandalous luxury displayed in fish-preserves, and the unwearied attention then directed to marine-animals, have furnished no other result useful to pisciculture. The only fact worthy of remark at this epoch of sterile extravagance is the introduction of gold-fish into artificial ponds, where shell-fish were also placed for their nourishment.

We may pass rapidly over the immense interval which separates the Roman Empire from the eighteenth century, without remarking any important progress in the husbandry of the waters. The fisherman's art was, however, extended and perfected during the middle ages, and fish-preserves became extremely numerous in France and Italy. Kings and princes all had artificial ponds in their domains, and we behold Charlemagne himself taking great pains to keep his own in repair, causing new ones to be dug, and giving orders that the fish produced should be sold. The religious communities exacted enormous duties upon almost all fisheries, and had considerable preserves in which multitudes of fish grew fat. The maintenance of these preserves required many precautions, and the restorer of agriculture in the thirteenth century (Peter of Crescenza) pointed out the manner of getting the greatest result from the lakes of fresh as well as salt water. There appears in his work, however, no method worthy of being noticed here, and the

*De Re Rustica, book viii, section 17.

†For further details, see Noel de la Morimière, History of Fishes, vol. i, 1815; Cuvier and Valenciennes, Natural History of Fishes, vol. i, 1828; and Dureau de la Malle, Political Economy of the Romans, vol. ii, 1840.

treatise does not appear to us to have rendered any more service to pisciculture than that of Florentinus in the third century, at least as far as we can judge of the latter by the extracts which Cassianus Bassus has preserved for us. It appears, nevertheless, that toward the end of the middle ages new methods were sought for, which might serve to increase the production of fish; a monk of the abbey of Réome, near Montbara, named Dom Pinchon, conceived the idea of artificially fecundating the eggs of trout by pressing out in turn the products of a male and female of this species into water, which he afterward agitated with his finger. After this operation, he placed the eggs in a wooden box having a layer of fine sand on the bottom, and a willow grating above and at the two ends. The apparatus remained plunged, up to the moment of hatching, in water flowing with a gentle stream. This process is described in a manuscript dated 1420, and belonging to the Baron of Montgaudry, grand-nephew of our celebrated Buffon. It has never been published, and had remained secret till a recent time.* Dom Pinchon is then, in all probability, the first inventor of artificial fecundation; but his experiments must be looked upon as not having occurred, since they were not made public. They have, of course, had no influence on the progress of pisciculture, and are only interesting in a historical point of view.

The fishery of Commachio on the Adriatic, of which the origin is probably very ancient, presents some natural features, which may, perhaps, be imitated with advantage on other parts of the Mediterranean shore. Already described at length by Bonaveri, then by Spallanzani, this lagoon still merits that we should say some words with regard to it. It is, perhaps, one hundred and thirty miles in circumference, according to Spallanzani, and is divided into forty basins, surrounded with dikes, and all in communication with the sea. Eels abound there to such an extent that the inhabitants sell them through all Italy. During the months of February, March, and April, they leave the gates open and all the passages free; the young eels enter of their own accord, and the more abundantly in proportion as the weather is stormy. This they call the "mounting." Once in the basins, the fishes find nourishment so abundant and so well suited to their wants that they do not attempt to leave until full grown; that is, after about five or six years. The eels emigrate, and are taken in the greatest number during the months of October, November, and December. For this purpose the fishermen open at the bottom of the basins little passages bordered with reeds, which the eels follow from choice, and are conducted into a sort of narrow chamber, where they accumulate without being able to get out. On the average, the crop amounts annually to a million of kilogrammes, (2,204,737 pounds,) and M. Corte informs us that it produces, according

*M. De Montgaudry explained the hatching-box of Dom Pinchon at one of the last sessions of the Zoological Society of Acclimation, and was kind enough to inform us also of the manner in which the monk of Réome effected the fecundation of the eggs.

to the estimate of M. Cuppari, a net revenue of 80,000 Roman crowns; that is, about $88,000.

The fishers of Commachio profit, as we see, by the advantages which nature offers, and they have but few precautions to take to insure the development of the fish in this great preserve. The less favorable circumstances in which the fisheries of the Swedish lakes were carried on induced an investigation, toward the middle of the last century, of the means of preventing the considerable loss which the spawn had there to undergo. Already great care was taken in that country not to trouble the fish at the times of their reproduction, so that it was even forbidden to ring the bells during the spawning-season of the bream. A counselor of Linkoeping, Charles Frederic Lund,* remarked that the three species most esteemed among those which inhabit the lakes of that country, the bream, the perch, and the mullet, attach their eggs near the banks, either to the rocks, or, by preference, to the twigs of pine and to the willow cages placed in the water to catch them. The eggs are thus destroyed by the fisherman, or devoured by insects, birds, and especially the fishes of prey, so that hardly one out of ten finally escapes. He well understood that the prohibition of fishing during the spawning-season would very imperfectly prevent this enormous destruction. He devised another means of protecting the multiplication of the fish, which accords completely, as he himself remarks, with the habits of these animals, the mode and the laws of their reproduction, as well as with the rules of logic and of our own duty. He caused large wooden boxes to be made without covers, but pierced with little holes, and furnished with rollers, to allow of their descending easily into the water. He placed twigs of pine in them, and introduced a certain quantity of males and females, taken at the time of spawning, taking care to separate them by their kinds and to give them space enough. After having left them there two or three days—that is, during the time necessary for laying the eggs—he drew out all the fishes with the help of a small net, and arranged the boughs so as not to press too much against one another. The eggs arrived at maturity after a fortnight, or a little more, according to the degree of heat, and a multitude of young fishes came forth. This simple process included all the conditions necessary to success, and doubtless great advantages may be found in it for the propagation of fishes whose eggs are adherent. Lund succeeded in transporting from one lake to another boughs covered with spawn, which he placed in a vase of water, taking care merely not to expose them to contact with the air. In making a first application of his process, he had put separately into three large boxes, with a small number of males, fifty female breams, which gave him 3,100,000 of the fry; one hundred perch of the large species produced 3,215,000 of the fry; and one hundred mullets gave 4,000,000 of little ones. He obtained then in this manner more than ten millions

*Of the Planting of Fishes in Inland Lakes. Memoirs of the Swedish Academy of Sciences, vol. 23, 1761. German translation of Kartner p. 184.

of young fishes, which were dispersed in the Lake of Raexen. If this process had been employed on a large scale in all the lakes of Sweden, there would have resulted, says he, a real blessing for the country.

The favorable circumstances of the arrangement adopted by Lund enabled him to observe some particulars of the development of the embryo. A German naturalist, Bloch,* advanced somewhat farther in this direction by employing a similar means. He took from the Spree some aquatic plants covered with eggs of perch, bream, rotengle, &c., and kept them in a wooden box of fresh water, renewed daily. At the end of a week he obtained many thousands of little fish; observing, however, that only a small part of the eggs were fecundated, and that those which were so remained transparent and yellow, while those which failed became daily more disturbed and opaque. Bloch concluded that by transporting spawn upon plants, as he had done, lakes and ponds might be easily and cheaply stocked with fish; but he made no experiment, and, as we see, only imperfectly imitated Lund.

While the ingenious predecessor of Bloch was seeking the means of increasing the inhabitants of the Swedish lakes, a lieutenant of miltia of Lippe-Detmold, in Westphalia, J. L. Jacobi, conceived the idea of artificially fecundating the eggs of fish, and of applying this process to the repopulating of ponds and rivers. The curious results of his experiments were, indeed, embodied in a letter, which the "Magazine of Hanover" only published in 1763;† but as early as 1758 Jacobi had addressed manuscript-notes upon the subject to the illustrious Buffon, which Lacépède has mentioned in the first volume of his "Natural History of Fishes," and in the course of the same year he had intrusted another account of his labors to the Count de Goldstein, grand chancellor of Berg and Juliers. Goldstein caused a Latin translation of it to be made, which he sent M. de Fourcroy, director of fortifications at Corsica, and an ancestor of the celebrated chemist. This version was published for the first time in French in 1773, in vol. iii of the "General History of the Fisheries" by Duhamel-Du Monceau. Duhamel does not mention Jacobi; but the facts in both memoirs being perfectly identical and set forth in similar terms, it is impossible not to perceive that both writings emanate from the same author. The date of the first communication entirely secures the claims of Jacobi, which are besides confirmed by the quotations of Lacépède, and by a communication made in 1764 by Gleditsch to the Academy of Sciences at Berlin. We give the details, because, the name of Goldstein alone having been printed in the "History of the Fisheries," many naturalists have wrongly attributed to him the merit of the discovery of artificial fecundations.

The experiments of Jacobi were upon the two most esteemed species

*Marc Eliezer Bloch, General and Particular Ichthyology, part ii, p. 94, 1795.

†It is to be found also, *in extenso*, in William Yarrell, History of British Fishes, vol. ii, p. 87, 1841; and at the end of Practical Instructions upon Pisciculture, by M. Coste, 1853.

of fish, the trout and the salmon. He tells us himself that, before arriving at good results, he had to employ sixteen years in preparatory researches and incomplete experiments. He remarked, in the first place, that from the end of November to the beginning of February the trout come together in the brooks and fix themselves upon the gravel, where they rub their bellies in a way which leaves large tracks. The females then deposit their eggs, upon which the males drop their milt. He caused some trout, then, to be taken at this season, when ready to spawn; taking by turns a female and a male, he pressed their abdomen lightly over a vase half filled with water, and let fall into it the mature products of both sexes, and then stirred up the whole with his hand, in order to render the mixture more complete, and thus to insure the fecundation of all the eggs. These eggs being once fecundated, it was necessary to combine the circumstances proper for their development, and for this purpose Jacobi thought of placing them in a grated box, across a little brook of running water. He constructed a large chest, at one extremity of which, and on the upper surface, he left a square opening, barred by a metallic grating of which the threads were separated by a space of only about four lines; this opening served to let in the water. Another, grated in like manner, and placed in the vertical face of the other extremity, allowed it to flow out. The bottom was overlaid with an inch of sand or gravel. Jacobi placed this apparatus in a trench prepared for it by the side of a brook, or, better still, a pond fed by good springs, from which he could cause, by a canal, an uninterupted stream of water to flow through the box.

These dispositions, very simple and judiciously combined, completely resolved the problem which he had proposed to himself, viz: To protect the fecundated eggs against their natural enemies and yet to leave them in circumstances similar to those in which they would naturally have been placed. The experiment succeeded. After about three weeks, Jacobi saw appearing through the thick envelope of the egg two black points corresponding to the eyes of the animal, and eight days later he began to distinguish the body itself, which moved and turned in the interior. Finally, after five weeks, the young fishes broke from their shells, and soon separated themselves completely from it, retaining only, under their bellies, a hanging yellow pouch, which is the umbilical vesicle. During nearly a month the young were nourished by the substance of this pouch, which disappears as they increase in size; but then they had need of other nourishment, and to obtain it they left the box by passing through the grating, and fell into a reservoir filled with sand and fitted to receive them. Jacobi adds that, in a basin of sufficient size, they grew wonderfully in the space of six months, and that then they had arrived at a suitable growth for stocking the ponds; but he does not say in what way he nourished them during all this time.

The inventor of artificial fecundation appears to have often repeated the experiments which he describes, and took great pains to insure the success of them. He perceived that the eggs are easily spoiled when they get into heaps, and recommends, to avoid this danger, the separating them frequently by means of a switch. Care should be taken also that they do not stick together when the milt is poured over them. Finally, the dirt which the water deposits should, from time to time, be carefully removed from them, and this may be readily done with the feather of a quill.

The question now is, whether Jacobi, by neglecting no precautions, and guarding himself against the various chances of failure, did arrive at a final result which is completely satisfactory in a practical point of view. Did he succeed by means of his process in advantageously restocking water-courses which had become unproductive, or increasing production, to any extent, in those where fish were already abundant? We have not the requisite documents for answering this question positively; but we can scarcely doubt that he obtained at least partial results, since England recompensed his services with a pension, and in a little state of Germany his operations have been continued with success by M. Schmittger.*

Physiology soon turned to account the discovery of Jacobi, and artificial fecundations have since been frequently reproduced in laboratories. There is no need of recalling the results which Spallanzani, Prevost of Geneva, and Dumas have drawn from them. They have been also a great help to embryological studies; and by employing this means two contemporaneous zoologists, Rusconi and C. Vogt, have been able to follow all the phases of development of the tench and the palie; but this discovery especially marked a great progress in pisciculture, and, while science availed itself skillfully of this new mode of investigation, the practical results obtained by Jacobi were carried out in Germany and Scotland.

In the "Treatise on the Economy of Ponds," (by Ernst Friedrich Hartig, p. 411, 1831,) there is given a description of the process of Jacobi, with the remark that this method has been successfully employed by the forester, Franke, at Steinburg, in the principality of Lippe-Schaumburg, as well as by M. De Kaas at Bückeburg. The same facts are confirmed by M. Knoche,† who asserts that he has himself also completely succeeded upon the estate called Oelbergen. The last writer placed the young fish at first in a little reservoir, and the following year transported them into a larger basin. "I have obtained by this process," says he, "in the eight years that I have been employed, 800 young fishes out of 1,000 to 1,200 eggs. After a year I found in the smaller pond only about half the fish, the others having either died or escaped.

*This fact is proved by a letter of Dr. Schutt, of Frankfort, recently written to Mr. Milne-Edwards. The experiments of M. Schmittger have been made in the principality of Lippe-Detmold.

† Journal of the Agricultural Union of the Grand Duchy of Hesse, No. 37, p. 407, 1840.

Apart from this loss, they succeeded very well, and I have obtained in three years, out of the fish, in this manner, a crop of three to four hundred trouts a year, of three to four years of age, and of which the largest weighed three-quarters of a pound." M. Vogt, in a letter recently published, which reproduces this passage of M. Knoche, informs us at the same time that a decree of the government of Neufchatel, issued in 1842, gave complete instructions to the fishermen as to the method of artificially fecundating the eggs of fish.

Some experiments have also been made in England and Scotland. After having studied during several years the manner in which the salmon spawn naturally, Mr. John Shaw* attempted to combine the conditions which appeared most essential in some preserves which he caused to be made near the river Nith. These reservoirs were only two feet in depth, and spread with a thick bed of gravel. They were fed directly by the water of a spring, which abounded with the larvæ of insects. A close grating was placed before the conduits, by which the surplus of this water had to flow out to gain the river. These dispositions once made, Mr. Shaw fecundated the eggs just below the point where the water fell into his basins, and left them to develop at the same spot. This plan succeeded, and he was able to bring up a certain number of young salmon during two years, and even more. He took advantage of them to make observations upon their growth and change of color. At the age of six months the young salmon had a length of two inches; of a year, three inches and three-quarters; of sixteen months, six inches; and of two years, six inches and a half. At this last period, when they had put on the livery of emigration, and when they are called in Great Britain by the name of parr, the milt of the males had arrived at a sufficient state of maturity to be able to fecundate the eggs of adult females. We owe also to Mr. Shaw, as well as to Mr. Andrew Young† and Dr. Knox, our increased knowledge of various particulars relative to the monogamy of salmons, and to the maneuvres which the female performs on the spawning place, but these researches do not appear to have had any practical result worthy of attention.

An engineer of Hammersmith, named Gottlieb Boccius, published in 1848 a short treatise on the management of fish in rivers and streams. He extols in it the method of artificial fecundation, but without producing any positive fact to prove that he himself experimented with success.‡ Since that time he has assured Mr. Milne-Edwards that he had

* Transactions of the Royal Society of Edinburgh, vol. xiv, p. 547, 1840.

† Natural History of the Salmon, Wick, 1848.

‡ In a previous work by the same author, (A Treatise on the management of Fresh-water Fish, with a view to making them a source of profit to landed proprietors, by Gottleib Bubocci London, John Van Voorst, Paternoster Row, 1841,) there are directions on page 19 for the propagation of trout by the method used by Lund, of confining a male and female in a box sunk in the stream.

It is very evident from this work that the author at the time of preparing his manuscript makes no claim to a knowledge of artificial fecundation.

operated in 1841 upon the water-courses belonging to Mr. Drummond, near Uxbridge, then upon the estate of the Duke of Devonshire at Chatsworth, upon that of Mr. Gurnie at Carsalton, and that of Mr. Hibberts at Chalfort. Mr. Boccius must have raised already about two millions of little trout.

The discovery of Jacobi had passed successfully, as we have seen, the trial and application in England as in Germany. Up to 1848, nevertheless, France had remained very much behind in experiments of this sort. Although she, perhaps more than any other country, had need of effectual means for remedying the impoverishment of the waters, the French economists had given scarcely any attention to this question. A single one, the Baron of Rivière, presented, in 1840, to the Central Society of Agriculture, some very learned and sensible reflections upon ichthyology regarded in its relations to the wants of man and the profits of agriculture.* He insisted especially on the advantages which would result from taking in the spring the *bouirons* or little eels which abound at the mouths of rivers, and dispersing them in the lakes, ponds, pools, and even muddy ditches, where they live very well. He satisfied himself that they might be transported alive in casks full of water, without appearing to suffer much from it; but wherever it should be possible to use rivers or canals, he thought it better to make use of boats pierced with holes in communication with the water, such as are frequently used for keeping fish. In this memoir of M. de Rivière, the word pisciculture is used for the first time; he employs it with hesitation to indicate this new branch of rural economy, which, says he, is still to be created.

II.

The year 1848 saw a new era commence in France for the economy of the waters. We believe it is just to say that if the application of artificial fecundation to the repopulating of rivers is owing to a German naturalist, it is in our country that pisciculture has grown, has been per-

In his work published in 1848, (Fish in Rivers and Streams, a treatise on the production and management of fish in fresh water by artificial spawning, breeding, and rearing, showing also the cause of the depletion of all rivers and streams, by Gottleib Boccius, London, John Van Voorst, Paternoster Row, 1848,) after describing apparatus for the incubation and care of eggs he says, on page 32: "Six years have I successfully carried out this arrangement with trout in a fishery not far from London, which is now the richest stream in the south of England. The principle of artificial spawning I have been acquainted with as far back as 1815;" after which he describes the processes of artificial fecundation of eggs.

The statement made by Boccius to Milne-Edwards, repeated by M. Coste and subsequent writers, that he applied the art of artificial fecundation in England in 1841, seems to indicate an inconsistency with reference to the dates. The evidence from his first work has, of course, no bearing upon the matter other than to indicate that he had not practiced the art at the time of preparing the book. But his *claim* in his second book, that for six years he had practiced the art, would not carry him back to the autumn of 1841, unless it were the fact that the manuscript had been prepared more than a year before the date of *publication*.—J. W. M.

* Memoirs of the Central Society of Agriculture, vol. xlviii, p. 171, 1840.

fected, and has finally come to constitute an actual branch of industry. All the progress which has been made within six years in this department of the science is the work of French inquirers.

The first, M. de Quatrefages,* was led by purely scientific researches to occupy himself with the multiplication of fish. This zoologist, convinced that artificial fecundation would do away with the various causes which prevent the development of the eggs, advised the employment of the hatching-box of Goldstein (or rather of Jacobi) for fish of running water. For those of ponds or lakes he recommended depositing the fecundated egg on a layer of aquatic plants in a spot where the water should be tranquil and shallow, and protecting them by lattice-work against the attacks of their enemies. He showed how the employment of the process discovered by Jacobi would facilitate the domesticating of foreign fish in our waters. Finally, he pointed out the possibility of rendering annual the triennial and irregular product of the ponds by dividing them into three or four unequal compartments. In the smallest the eggs might be hatched and the fry raised. Each year the fish might be driven from one compartment to another, and the last basin might be fished every year.

The memoir of M. de Quatrefages made a good deal of noise, because it met one of the wants of rural economy, and gave a glimpse of a quite new prosperity for the industry of ponds and water-courses. Drawing from oblivion the results obtained in Germany during the last century, it recalled the attention of naturalists and husbandmen to a question too long neglected, and of which it would be now superfluous to dwell upon the importance. The author was, doubtless, far from thinking that the conclusions to which he had brought his studies would be almost immediately justified and confirmed by the experiments taken some years before, but which had not yet been made public. However, in the first days of March, 1849, the Academy of Sciences learned by a letter of Dr. Haxo,† secretary of the Society of Emulation of the Vosges, that this society had, in the year 1844, given a premium to two fishermen of La Bresse, MM. Rémy and Géhin, for having fecundated and artificially hatched some eggs of trout. M. Haxo added that Rémy and Géhin then possessed a piece of water containing five or six thousand trout, of one to three years old, all raised by this process. It is impossible not to admire the sagacity and perseverance of these fishermen, who, quite unlettered and ignorant of the progress of the natural sciences, have found the means of themselves, of remedying the decay of their industry, and of giving it a new impetus. Not only have they repeated, with great pains, the observations and experiments which occupied Jacobi's whole life, but they have gone much farther in the practical application, and have almost entirely resolved the problem.

* Comptes-rendus of the Academy of Sciences, vol. xxvii, p. 413, 1848. See also the Revue des Deux Mondes, Jan. 1, 1849.

† Comptes-rendus of the Academy of Sciences, vol. xxviii, p. 351, 1849.

Although they have both greatly contributed to the success of the undertaking, we now know that the first efforts were solely owing to Joseph Rémy, and that he associated Antoine Géhin with himself only after having already half succeeded. Rémy first studied the habits of the female trout ready to spawn. He saw them remove the gravel with their tails, and rub their bellies to assist the laying of the eggs. Having caught many of them in this state, he perceived that by pressing them a little with his hand, he could easily force out the mature eggs, and that the same thing occurred with the milt of the males. He next suspended a female above a vase full of water, and by means of a light pressure applied from above downward, he caused the eggs to fall out, upon which he afterward poured, in like manner, the fecundating liquid of the male until the water was white. Next depositing the eggs in a tin box pierced with numerous holes, and spread with a layer of coarse sand, he placed the box in a fountain of pure water, or in the bed of a brook; after a certain time he saw the young hatched, and freeing their tails first.

These facts, which Rémy relates himself in a letter addressed, in 1843, to the prefect of the Vosges, are, as we see, almost identical with those which Jacobi has embodied in his memoir, as these last were with the experiments of Dom Pinchon; but the two fishermen of La Bresse did not stop there.* It was not enough to have guarded the eggs against the chances of destruction, which menace them when abandoned to themelves. It was necessary also to insure the development of the young, and to find for them a nourishment suited to the wants of their age. This Rémy and Géhin succeeded in doing. After two or three weeks of a diet adapted to these wants, they opened the boxes which contained the fry, and allowed them to run freely into a water-chamber or a portion of the stream prepared to receive them. There they had taken care beforehand to raise a great number of frogs, of which the spawn is eagerly devoured by the young trout. Somewhat later they had recourse to the method already employed for the support, in preserves, of adult carnivorous fishes.†

Rémy and Géhin first stocked two ponds near La Bresse, several brooks of their canton, the water-courses of the commune of Waldenstein, and have thrown about fifty thousand young trout into the Mose-

*Haxo d'Espinal on the Artificial Fecundating and Hatching of the Eggs of Fish, 2d edition, p. 22, 1853; and Guide of the Pisciculturist, 1854.

†"To nourish their young trout," says M. de Quatrefages, "they hatched with them other smaller species of fish, smaller and herbivorous. These are raised and nourished upon aquatic vegetables. In their turn they serve for food to the trout, who are nourished by flesh. These fishermen have thus succeeded in applying to their industry one of the most general laws, upon which are based the natural harmonies of the animal creation." In view of the necessity of their carnivorous diet, it is important to put together only trout of the same age, otherwise the smaller become the food of the large; and even with this precaution, it is not always possible to avoid the fatal effects of their voracity.

lotte, one of the affluents of the Moselle. These results were too important, and promised too great advantages in the economy of our waters, not to draw the attention of the public, and even of the government. In 1850 M. Milne-Edwards was officially charged by the minister of agriculture to make sure of the accuracy of the facts published, and to ascertain their value. After having procured some information in England as to similar experiments, he went into the Vosges, and visited the little establishment of the fishers of La Bresse. In a very remarkable report,* he gave an account of the interesting labors of Rémy and Géhin, and, while pointing out that the discovery of artificial fecundation dated back into the last century, he proclaimed that the fishermen of La Bresse were the first to make application of it among us, and that they have the merit of having thus created a new branch of industry in France. The learned dean of the Faculty of Sciences of Paris resolved upon a grand experiment of stocking the waters of France with fish and regarded the success of it as probable if the processes were judiciously arranged. It appeared to him that the best recompense which the government could make to the fishermen of La Bresse would be to give them the direction of the enterprise. The Philomatic Society did not hesitate to put forth a similar wish by the organ of M. de Quatrefages.†

The first notice of M. de Quatrefages, the promulgation of the success obtained at La Bresse, and the favorable report of M. Milne-Edwards gave a powerful impulse to pisciculture, and induced varied applications of it on all sides. Under the influence of these first labors, commenced, in many parts of France, the grand trial which is now going on. Its value will not be fully known till it is completed; but it is already sufficiently advanced to permit us to hope that in the majority of cases the method of artificial fecundation will produce important results. A certain number, both of eminent men of learning and of men of practical skill, have taken part in this movement, which, far from slackening, increases, on the contrary, and is extending daily more and more. Among those who have contributed most by their writings or their practical studies to the continually increasing progress of pisciculture, besides Rémy and Géhin, besides M. Milne-Edwards and M. de Quatrefages, we must mention M. Valenciennes, whose knowledge of ichthyology is so extensive and profound; M. Millet, inspector of waters and forests; M. Coste, professor in the college of France; Messrs. Berthol and Detzem, engineers of bridges and causeways; M. Paul Gervais,‡ at Montpellier; M. J. Fonmet,§ at Lyons; Mr. F. Defilippi,¶ at Turin.

M. Valenciennes|| has, at least in part, realized the hope which has

* Annales des Sciences Naturelles, third series, vol. xiv, p. 53, 1850.
† Journal of Practical Agriculture of June 5, 1852.
‡ Bulletin of the Society of Agriculture de l'Herault, July, 1852.
§ Memoirs of the Society of Agriculture of Lyons, May, 1853.
¶ Importanza economica dei pesci e del Coro allevamento artificiale.
|| Report on the Species of Fish in Prussia, which might be imported and acclimated in the fresh waters of France.

often been indulged, of transporting and domesticating in the waters of France the most esteemed fish of foreign countries. He has succeeded in bringing alive from the Spree to the reservoirs of Marly five different kinds, each represented by a certain number of individuals. There are the sander, (*Perca lucioperca, of* Linne) the wels or silure, (*Silurus glanis,* of Linne,) the Alandt, (*Cyprinus jeses,* of Bloch,) the German lotte, (*Gadus lota, of* Blech,) and the pitzker (*Cobitis fossilis,* of Linne.) This trial has only been made on a small scale, but it is none the less important on that account, since it proves that, in ordinary circumstances, difference of waters would not be an absolute obstacle to the acclimating of foreign fish.

The same gentleman was afterward charged by the minister of marine with the duty of inspecting the fisheries of our coast. The report, in which were embodied the observations made in the course of this mission, has remained unpublished, and it is to be regretted that the learned ichthyologist was not able to continue and extend these researches, to which his previous studies so naturally called him.

It is worthy of notice what wise circumspection MM. de Quatrefages and Milne-Edwards have employed in presenting the advantages which rural economy might derive from the method of artificial fecundation. They have incited the proprietors to attempts which appeared likely to be advantageous, but without always promising them certain results. M. Coste has proceeded with less reserve. With unlimited confidence in the future of pisciculture, he has allowed no occasion to pass without exalting the benefits which it will confer. In his first report, at the close of the year 1850, he declared already "that there is no branch of industry or husbandry which, with less chance of loss, offers an easier certainty of profit."* Later he speaks with enthusiasm of the means tried during a century of providing for the repopulating of the waters. Most certainly it is with excellent intentions, and, doubtless, in the hope of sustaining the efforts of experimenters, that M. Coste thus undertakes to guarantee future results; but is it not rather to be feared that, in magnifying too greatly some partial successes, he may compromise the general success of the undertaking? Meanwhile, though these absolute affirmations seem to justify, to some extent, some criticisms of which the learned professor has been the object, they cannot diminish his share in the improvements recently made in the method of Jacobi.

M. Coste first put in practice the means proposed by the Baron de Rivière for transporting the "mounting," or the young eels, and raising them in confined spaces.* After having brought this mounting from the mouth of the Orne to the College of France, in flat paniers, overlaid with aquatic plants, he gave them for nourishment a hash composed of the flesh of animals, which do not serve for food or that of

* Practical Instructions upon Pisciculture, p. 34.

molluscs and earth-insects. The little eels, which, on arriving, had an average length of six and seven centimetres, (two and one-half to three inches,) and a circumference of one centimetre, had arrived, after twenty-eight months of this diet, at thirty-three centimetres of length, and seven of circumference. M. Coste remarks with reason that the corpses of the vertebrated animals, which are not fit for the food of man, might be made useful in this manner. He adds that the noxious insects would serve quite as well to fatten the fish. "Thus a great service would be rendered to agriculture, since it would, in the end, be delivered of one of its s ourges." It is to be regretted that the learned professor has not entered into any details upon the best method of capturing these insects, which the cultivators have so great an interest in getting rid of, even if they could not make a profitable use of them.

The author of the Practical Instructions upon Pisciculture has been at length induced to take charge of the organization of a vast establishment of artificial fecundation. In 1850 the two engineers of the canal from the Rhone to the Rhine, Messrs. Detzem and Berthol, after having visited La Bresse on the invitation of the prefect of the Doubs, had applied at Huningue the method of Rémy and Géhin. Upon the basis of their first experiments they had undertaken hypothetical calculations, from which it appeared that the present population of the waters of France does not exceed twenty-five millions of fish, producing annually less than six millions of francs ($1,200,000)—which figure is really much too large—while, if the process of artificial fecundation were everywhere introduced, the number of fish would be raised, after four years, to three thousand one hundred and seventy-seven millions, and would produce a revenue of nine hundred millions of francs ($180,000,000.)* At Lochlebrunn, some kilometres from Huningue, MM. Detzem and Berthol had established the foundations of a large preserve, where in 1852 they operated numerous fecundations by means of a hatching-box which in no respect differs from that of Jacobi. They assert that they have there obtained a cross of the trout and salmon.†

The minister of agriculture directed M. Coste to visit the new establishment. In a report, favorable to the labors of MM. Berthol and Detzem,‡ the professor of the College of France asked for and he succeeding in obtaining a considerable development of the fish-preserve, or *piscifactory*, as he proposed to call it. He brought into use on a large scale a hatching-apparatus, which we shall have to describe, adopted all the measures which he thought most fit; and in his memoir upon the means of restocking the waters of France, he undertook, before the Academy of Science, to make a delivery in June, 1853, of six hundred thousand trout and salmon, large enough to be thrown into our rivers. We have not visited the establishment of Huningue, and know

* Artificial Fecundation of Fish: Society of Emulation of the Doubs, p. 18, 1851.
† Report upon the facts proved at Huningue from May 8, 1851, to May 7, 1852.
‡ Practical Instructions in Pisciculture, p. 96.

not whether it is organized in a way to fulfill a part of the promises which its founders have often put forward; but from the information which has reached us from several quarters, it would seem that their success has not always been as complete as was hoped for at first. It is then much to be feared that after four years, and even more, the establishment of Huningue will not have succeeded in alone restocking with fish all the waters of France, and in making them produce the nine hundred millions of francs promised by MM. Berthol and Detzem.

However this may be, the relations established between this piscifactory and the College of France have furnished to M. Coste an opportunity of making some curious observations on the transport of the eggs, and the duration of their vitality after having been taken from the water. Some eggs of salmon and trout, sent from Mulhausen by the diligence, were hatched in great numbers at the College of France. The precaution had simply been taken of surrounding them with moist aquatic herbs in a tin box pierced with holes on the upper side.* Other eggs, artificially fecundated, arranged in layers with wet sand in a pine box, remained thus two months in a cold chamber. At the end of this time they were only corrugated; but having placed the box in water to moisten them through the sand, M. Coste saw them soon resume their natural appearance, and they hatched soon after.

To render possible in his labratory the experiments which he had undertaken, M. Coste had to adopt an apparatus occupying but little space, and for which a simple thread of water would suffice. The arrangements which he chose are very simple. This apparatus, which, by the way, we have often seen in operation, is an assemblage of little troughs arranged like steps on each side of an upper trough which serves to supply all the others. The bottom of each trough is covered with a bed of gravel. A stop-cock lets fall a continuous thread of water into one end of the upper trough. A current is thus created toward the other end, and there an opening at the sides giving it passage to right and left, it breaks into two falls of water which go to feed the two troughs placed immediately below. These last have also openings by which the water falls into the lower troughs, the number of which may be increased at pleasure.

After the hatching obtained by this apparatus, M. Coste was able to inclose two thousand young salmon into a canal of baked earth, having fifty-five centimeters in length, (twenty-one inches,) fifteen in breadth, and eight in depth, where, says he, the current is kept up by a simple thread of water of the size of a straw. He gave them for nourishment a paste formed of muscular flesh reduced to fine fibers, in preference to the boiled blood of which Rémy and Géhin had made use. A salmon raised in this manner in an artificial pond two meters in length, (eighty inches,) and fifty centimeters in breadth, (nineteen and one-half inches,) was, at the age of six months, larger than those of the same age taken

* Comptes-rendus of the Academy of Sciences, vol. xxxiii, p. 124, 1852.

in the Scottish rivers, and represented in the work published under the assumed name of Ephemera.* Such are the principal results to be ascribed to M. Coste. He has recently collected his memoirs and reports into a volume, under the title of "Practical Instructions upon Pisciculture." He sets forth in these instructions the knowledge previously acquired, and those which he has drawn from his personal experience, and he adopts some of the improvements introduced by M. Millet in the practice of the new industry. We regret that the author of this little work, written with much elegance and clearness, has not oftener cited the sources from which his information is taken.

The same day upon which M. Coste presented his work to the Academy of Sciences, M. de Quatrefages read before this learned body some researches upon the milt of certain fresh-water fish.† The question here treated of is fundamental; and before it had been resolved, it was impossible to use the necessary precision in artificial fecundations. This labor is then of great importance in the double point of view of comparative physiology and the application of zoology. We know by the experiments of Prevost, of Geneva, and of M. Dumas, that the milt owes its physiological properties to the presence of animalcules, which move in a manner very peculiar, and that all fecundating-power disappears the moment that these animalcules die. Now, M. de Quatrefages shows that the duration of these movements is extremely short in the case of fish, even in the most favorable circumstances. Thus, in the milt of the brochet, diluted with water, all vitality ceases after eight minutes and ten seconds; the animalcules of the mullet are all dead after three minutes and ten seconds; and those of the carp after only three minutes. This period of activity is still more limited for the perch and barbel, since it only reaches two minutes forty seconds for the former, and two minutes ten seconds for the latter. Neither is it equal for all the animalcules of the same fish, and half of them perish in much less time. Besides, the preceding figures are taken at the degree of heat most favorable to the duration of these movements, and even slight variations above or below this point destroy them with great rapidity. The temperature which maintains longest the vitality of the animalcules is, for winter-fish like the trout, forty-one to forty-eight degrees of Fahrenheit; for those of the early spring, fifty to fifty-five degrees; for those of later spring, as the carp and the perch, sixty-three to sixty-eight; and for the summer kinds, seventy-seven to eighty-seven. When the temperature somewhat exceeds these limits the increase of energy on the part of the animalcules compensates, to a certain extent, for the shorter duration of their vitality. These results apply to those which are disseminated through the water; when they remain united in small

* The Book of the Salmon, by Ephemera, [E. Fitzgibbon,] assisted by Arthur Young. See also the Agronomic Annals, vol. i, p. 234, 1851.

† Comptes-rendus of the Academy of Sciences, session of May 30, 1853, vol. xxxvi, p. 936; Annals of the Natural Sciences, third series, vol. xix, p. 341., 1853.

masses they die much more slowly. The peculiarities of the milt may thus be preserved for a much longer time when it is not diluted, and especially when it is kept at a very low temperature. It may even be frozen without causing in all cases the death of the animalcules. "M. Millet, who has aided me in all these researches," says M. de Quatrefages, "has thought of putting the milt with ice into a tin box, so that the water may run out as the ice melts, and then to arrange this box in a second wooden one, pierced with very small holes, and itself filled with ice." Thanks to these precautions, the learned academician has been able to preserve the milt in a serviceable condition during sixty-four hours. It is worthy of remark that the fecundating-property disappears first in that part of the male organ where the liquid is most completely elaborated, and endures some time longer in the deeper parts.

These facts taken together will explain most of the failures resulting from operations apparently well conducted. They show that the manipulations must be accomplished with great quickness, and careful attention must be paid to the temperature of the water. We may conclude from them also that the season of spawning in certain localities must vary in accordance with the atmospheric phenomena; that the short vitality of the milt is one of the causes which oppose the crossing of the different species in nature; and that the hitherto unexplained instinct which leads the trout and salmon to mount to the sources of water-courses is owing to the need felt by these animals of finding a degree of temperature suitable to the fecundation and development of their eggs. M. de Quatrefages has also deduced from his researches data of great value for practice, and eminently suited to regulating the methods of artificial fecundation.* The results contained in the memoir of M. de Quatrefages give to these methods a scientific regularity, which they have wanted hitherto, and tend to endow pisciculture with fixed and precise rules.

To complete the summary picture of the progress which pisciculture has made from antiquity to our time, and to show its present condition, it remains to point out the numerous and important improvements which are owing to M. Millet, inspector of waters and forests.†

* Since the male liquid, completely elaborated, loses first its fecundating-properties, only that should be used in doubtful cases which is pressed from the milt itself. The vitality of the animalcules not being destroyed by cold in the male organ, the frozen milt is not to be rejected as useless. If the fecundation cannot be made till after the death of the animal, it is well to take out the milt and preserve it in a wet cloth. In view of the extreme shortness of life of the animalcules, and of the obstacles which the swelling of the envelope may oppose to fecundation, it is useful in the case of certain species to pour the eggs and the male product simultaneously into the same vessel, and thus to render the contact instantaneous. Of course, the water must never be first impregnated with the milt.

† Report to the director-general of waters and forests upon the repopulating of the navigable and floating water-courses, by M. de Saint Ouen, administrator of the forests, March, 1853. Annals of the Forests, pp. 272 and 429, July and August, 1853. Independently of the various memoirs upon pisciculture which we have hitherto cited, it

It is a well-known fact that fish do not deposit all their spawn at once The eggs do not all arrive together at a state of maturity. When left to herself, the female returns several times to the place of spawning, where the male always follows her, and it is only after a certain number of days that the delivery of the eggs is complete. Although it has been already remarked that only the ripe eggs leave the ovary and find their way into the abdominal cavity, yet the advice was always given to effect the artificial fecundation at once by forcing out the spawn by pressure on the sides of the belly of the female. Without doubt, this practice, in many cases, was attended with a violence as injurious to the development of a great number of the products as to the health of the animals thus operated upon.

Struck with these inconveniences, and convinced of the advantages always following from a strict imitation of nature, M. Millet took pains to gather the eggs only in portions and in several days, as they became completely ripe, and to let them fall into the water simultaneously with the milt of the male. As captivity has often a bad effect upon the generative functions of fishes, M. Millet only takes them at the moment of making the fecundations, and restores them to the river immediately after, at the same time tethering them with a pack-thread passed through the gills. They live very well in this condition, and do not perceptibly suffer from it. M. Millet has also sometimes made use of artificial spawning-holes, which call to mind those of Lund, but are more perfect. These are a kind of double-bottomed cages, the first consisting of an open frame-work of bars, the second of a movable sieve of metallic cloth. The females, by rubbing against the bars, let fall their eggs, which drop upon the sieve. The males being introduced into the apparatus at the same time, it generally happens that the fecundation is effected naturally. This method of gathering has the advantage of losing no portion of the eggs, while there is risk of this in holding the female by a cord in rivers.

The hatching-apparatus used by M. Millet varies a little with circumstances, but remains always simple, convenient, and economical. If the development of the egg is to take place out of the water in which the parents live, whether in an *apartment* or under a shed, a vessel of any description is taken, having a capacity of thirty to thirty-five litres,

may be useful to consult the report of a commission of the King of Holland, having for title, "Handliedung tot de kunstmatige Veremenigouldigen van Vischen, 1853;" some notes of M. de Camnont in the Norman Annual for 1850, and in the same collection an Essay upon the Multiplication of Fish in the department of La Manchi, by M. G. Sward de Becunlieu, 1854, as well as some letters of the Marquis of Wibraye and the Count of Pontgibard, 1854; in the Analytic Sketch of the Labors of the Academy of Rouen, a note by M. Bergasse on Artificial Fecundation applied to the Salmon, 1853; and some Researches into the Natural History of the Salmon, by M. A. de Bignon, 1853; finally various observations of MM. Géhin, Richard de Behague in the Bulletin of the Agricultural Society of Paris, vol. vi, pp. 461 and 469, 1851; of M. Noblet, ibidem, vol. vii, p. 403, 1852, and M. Quenard, ibidem, vol. viii, p. 95, 1853.

(eight to nine gallons;) and on the bottom of this gravel, sand, and charcoal are heaped up so as to constitute a filter. A purified water runs from this reservoir by a stop-cock situated underneath it, and falls into troughs placed like steps, which may be multiplied at pleasure. This arrangement is entirely similar, as we see, to that which M. Coste had already chosen; but M. Millet has added an improvement, which, we hasten to say, the learned professor of the College of France has at once adopted in his turn.

However pure running water may be, it always bears with it and deposits at the bottom which it covers foreign particles, which, if they rested upon the eggs, would finally surround them with a sort of slime favorable to the development of byssus and mold. To meet this objection, M. Millet thought of suspending the eggs a little below the surface of the water. M. Vogt* had already taken the precaution to place them in a muslin bag, permeable on all sides, which he threw into the lake after having fastened it to a stake, or kept it in place by a large stone. Starting upon the same principle, M. Millet has arrived at a surer and more complete result. He places the eggs upon sieves, which little rods, sliding on the edges of the tubs, hold at the desired height. This skillful experimenter has successively employed sieves of various substances, of hair, of silk, of willow, &c., and has finally given the preference to galvanized metallic cloth, which have more solidity and durability, do not spoil, are easily cleaned by the help of a brush, and are only very rarely attacked by sea-weed.

The expense of outfit of such an apparatus is quite insignificant. The working consists merely in filling the reservoir every morning and evening, in moving the sieves once a day, and taking away the eggs which may become opaque. For many years the eggs of trout, of salmon, of the umber, &c., have been developed in this way, and hatched in considerable quantities in the same apartment which the experimenter occupies at Paris, in the middle of the rue Castiglione.

When the process can be carried on in the water of a stream itself, of a lake, or of a pond, M. Millet recommends the employment of double sieves of metallic cloth, which may be kept at a suitable height by the help of floaters, and which follow all the changes of the level of the water. For the species which spawn in sleeping water, he lines the double sieve with aquatic plants, or limits himself to placing the eggs in large shallow tubs with plants, which prevent the water from corruption. When the fecundated eggs are to be transported to great distances, M. Millet advises placing them in a flat box, in quite thin layers, between two wet cloths. In this state he has sent them to Florence, where they have reached the hands of M. Vaj and the Professor Cozzi, after a journey of twenty or twenty-five days, and have not failed to hatch soon after. The use of moist linen is preferable to that of aquatic

* Embryologie des Salmones; Histoire Naturelle des Poissons d'eau douce de L'Europe centrale, by L. Agassiz, p. 16, 1842.

plants; the linen dries less rapidly, and facilitates the unpacking, which, in the other cases, requires much time and care. The Marquis of Vibraye, to whom the Sologne owes so many useful improvements, and who has already introduced on his estates numerous trout produced by artificial fecundation, has also made use, with advantage, of small wadded cushions. When the eggs to be dealt with are very delicate, and are to be transported during the summer, M. Millet sometimes employs the little portable ice-box, of which we have already given the description.

As soon as the young fish have completely absorbed their umbilical vesicle, that is to say, some weeks after the hatching, the author of these curious experiments is of opinion that it is best not to try to nourish them in captivity, but to dismiss them at once into the waters where they will have to live, taking care, however, to place them suitably where they will find the spawn of frogs, lymneas, planorbis, &c. They should commence at once to seek for their prey, and thus avoid the suffering from change of water, of nourishment, and of habits, to which they will necessarily be subject, if raised artificially in basins not communicating with the waters which they must inhabit.

It is principally in the departments of the Eure, the Aisne, and the Oise that M. Millet has put in practice these various methods. Affidavits emanating from the local authorities bear witness to the important results which he has obtained. M. Millet has conducted, at the same time, a series of delicate observations, which have already led to some happy applications.* He has examined the action of salt or brackish water on the eggs of fish which leave the sea to spawn in fresh water, and he has seen that it is injurious to their development in ordinary cases, which gives the practical reason of the emigration of these animals. Nevertheless, salt, which would destroy the healthy eggs, has the singular property of healing them when attacked by white spots. These spots, which probably spread from the surface to the center, and would lead to the destruction of the eggs if allowed to increase, disappear in water very slightly salted; and when they are taken in time, the young fish may thus be saved. It results also, from the observation of M. Millet, that the mortality of the eggs always reaches its maximum at the epoch when the embryo begins to form; accordingly he advises transporting them only when the eyes become visible, or rather immediately after the fecundation. He has remarked, finally, that the white spots on the one hand, and the sea-weed and byssus on the other, attack much more rarely the eggs of trout and salmon, at a low temperature, than in one which exceeds fifty-four degrees.

Here terminates the rapid exposition of the applications furnished by zoology to the economy of ponds and water-courses, and of the prog-

* Comptes-rendus of the Academy of Sciences, vol. xxxviii, session of December 26, 1853.

ress which this branch of industry has made of later years. The labors of Rémy and Géhin, and those of M. de Quatrefages, of M. Coste and M. Millet, represent the present state of this department of agricultural science. To them belongs the honor of having regulated and perfected the methods, and of having determined the basis of a cultivation before very vague and precarious.

III.

The processes which we have analyzed are not all equally adapted for easy and profitable application. It remains then to compare the respective advantages of them, to determine the combined measures which pisciculturists ought to adopt.

The first care to be taken when it is desired to stock a river or pond is to learn what species of fish will best adapt themselves to the circumstances which happen to be united there. To escape the danger of certain failure, it is first of all necessary that the nature, the ordinary temperature, the depth, and the various qualities of the waters to be enriched should agree with the instincts, habits, and way of life of the animals to be developed there. These recommendations are found in all books upon the subject, but cannot be too often repeated. It is most certainly from the neglect of these proprieties, and want of appreciation of them, that certain pisciculturists have seen their attempts miscarry when they were otherwise skillfully executed.

When, therefore, the ground, as it were, has been studied in advance, and it has been determined what sort of fish has the best chance of prospering there, the individuals necessary for the multiplication of the chosen species should not be procured except at the very season of spawning, since very often the products are spoiled in the bodies of fishes which are condemned to close captivity. This inconvenience does not present itself if the animals can be placed in reserve in inclosures near the rivers or ponds in which they have been caught. Otherwise they may be held by a cord in the same places where they have lived. It is important, before effecting the fecundation, to pay attention to the temperature of the water, which has so great an influence upon the properties of the milt, as M. de Quatrefages has so clearly shown, and probably also upon the vitality of the egg itself. Although M. Vogt has seen the eggs of the palee* prosper after they had been taken in ice, this extreme cold is generally sufficient to destroy them.

The gathering of the male and female elements should be made on different occasions and in several days. It seems useful, in many cases, to guard the products from all exterior influences, and not to take them from their natural medium. For this purpose a male and a female are taken and inclined near each other at the surface of the water. They are then bent gently upward, which produces a strong contraction, and

* A species of white-fish (*Coregonus palea.*)

generally serves to create a flow of the ripe products. If the exit offers any difficulty, it may be assisted by passing the finger under the belly but without any effort. The simultaneous or almost simultaneous mixture of the eggs and the milt is necessary in most cases, since with certain fish, as the trout, the animalcules of the milt do not live even a moment, and with others, as the carp, the mucilaginous envelope of the egg swells rapidly in the water and, then opposes itself to the impregnation. For the last reason, it is important always to refrain from washing the eggs before fecundation, as some persons had advised doing.

The eggs once fecundated are placed in an apparatus like those of M. Coste and M. Millet; but it appears to us preferable in all cases, when possible, to employ the double sieve or floating insulator of the last experimenter. The fecundation is then effected in the lower part of the sieve, placed in a tub full of water; and after the cover is put on, the whole is transported to the river which is to be furnished: in this way the spawn undergoes no change of water, from its exit from the belly of the female to the period of its development. If the eggs are unencumbered, they are allowed to fall to the bottom of the sieve. If they are adherent, likes those of the carp, the tench, or the barbel, care is taken to introduce beforehand into the sieve some aquatic plants or twigs. The little apparatus is furnished with floaters, and fastened to stakes by a cord, by which it is easy to draw it to the bank, when it is to be examined. After the young fish are hatched, and their umbilical vesicle is completely absorbed, the sieve is opened, and they are thus dispersed in the very places where they are to live. With this view, shallow places are chosen, which the fry generally prefer, and which are not frequented by the large fish, or rather inclosures near the water-courses. The fish of this early age have great agility, and commonly escape the pursuit of their enemies by squatting among the pebbles, and concealing themselves in the grass or the roots of trees. They then feed naturally upon lymneas, planorbis, small worms, or the spawn of frogs, but it soon becomes useful to throw them the refuse of the shambles or the kitchen, and, generally, as M. Coste has advised, all animal substances which are not made use of. It would seem, however, that some of these substances may become injurious to the fish, and M. Sivard de Beaulieu has remarked that his trout always died after eating earth-salamanders. The putrefaction of the substances which are not eaten offers no inconvenience in a mass of water frequently renewed like that of a brook, while for this reason, and many others, the artificial nourishment of young fish in narrow reservoirs is almost impracticable. They should, therefore, always be dispersed after the absorption of their vesicles, without attempts to raise them painfully in small apparatus.

These various operations are, as we see, very simple and easy, and may be brought to a good result by anybody with little outlay of time and expense; but it is evident that success depends greatly upon the tact and foresight of the operator, and that here, as in all branches of industry, individual skill will always have great influence upon the result. Without doubt, also, a prolonged and sufficiently extensive experience will soon attain to further improvements in the application of the new methods, and reduce greatly the chances of failure. Everything, then, gives reason to hope that at an early period pisciculture will be naturalized among the useful sciences, and that it is destined to solve one of the important terms of the great problem of cheap living.

This result, so desirable, would be greatly expedited if the Government should decide to take some energetic measures. It should cause to be completely revised, by competent men, the legislation of the fluvial and marine fisheries, and should bring the system of artificial fecundation into operation, in all the fresh waters of France, at the same time that a service of observation and vigilance should be organized upon our coasts. In uttering this wish, we are only the echo of all the learned men and economists who have touched upon this question.

Already, indeed, the state has made a first step in the path where we should like to see it wholly enter. It has decreed the piscifactory of Huningue. We are far from denying the services which this establishment may render by its consequences; but it is clearly proved that it will never suffice for entirely restocking the waters of France, and meets very imperfectly the present wants of pisciculture. If there are too great obstacles to putting this vast trial in practice over the whole surface of the country, it would at least be easy for the state to undertake it in more limited though still considerable proportions, and without charging the budget with any new burden. For this purpose it need only profit by the resources offered by the administration of waters and forests. In fact, this administration disposes of a surface of canals and brooks which reaches nearly 8,000 kilometers, (5,000 miles,) and has a personal force quite ready and trained to the various practices for the husbandry of the waters. The number of its simple fisheries police amount to 427, without counting the general police, sub-inspectors, and inspectors which direct the others, and who are all prepared, by their previous studies for applications of this kind. Here is a service extensively organized, which would be admirably adapted to experiments of pisciculture on a large scale, and which would not, even thereby, be turned from its legitimate functions.

It is to be hoped that those who are interested will not fail to be struck with these easy advantages, and that they will try to attain to at least a part of the results promised by the new industry. Relying upon their own resources, the proprietors have not hesitated to undergo the risks of the trial; but apart from their isolated and limited efforts, does it not belong to the state to give prosperity and extension to the methods devised by Jacobi, and already carried by men of science in France to so high a degree of perfection?

B—REPORT ON THE PROGRESS OF PISCICULTURE IN RUSSIA.

By Theodore Soudakèvicz.

[Prepared for the Vienna Exposition of 1873, and translated from the French by H. Jacobsen.]

1.—THE DECREASE OF FOOD-FISHES.

The fact that basins which formerly abounded in fish show a decrease does not admit of any doubt, and it is even asserted with good reason that this is not an accidental phenomenon, which might be explained by unfavorable and passing circumstances, but that we have to face a constant and general fact.

In view of the great importance of the fisheries in regard to the question of food and economy, this decrease of fish must necessarily occupy not only scientists and naturalists, but also governments. Observation and experience have shown that the cause of this fact must not be looked for in a weakening of the reproductive powers of fish, which probably are as extraordinary at this day as they were in former times;* it must, therefore, be due to other influences, especially to those which are brought about by man's own doing.

The basis on which a rational system of pisciculture is founded is very simple, and can be limited to the following rules:

1. Preserve the natural conditions of those places where the fish spawn, conditions which favor the spawning-process, and tend to preserve the spawn and protect the first development of the eggs; thus, *e. g.*, everything which diminishes the supply of fresh water; everything which changes the quality of the water or the character of the bottom; everything which hinders the growth of aquatic plants; in fact, everything which at its very source can destroy the wealth of fish of a whole basin.

2. Leave a free passage for the fish to pass to the places which are favorable for spawning, at least as much as is necessary for preserving the species in sufficient quantity; for the best natural conditions for spawning would be useless, if nearly all the fish which went there were caught and destroyed during their journey.

3. Protect the young generation, so that it can arrive at the age of maturity and contribute its share toward the increase of the species.

If these conditions are observed, every large sheet of water, inland seas and large lakes, may become as rich in fish as the quantity of nutritive substance contained therein will permit. Certain hurtful influences such as, epidemics, or the too great development of animals which feed on spawn, can doubtless diminish the number of certain

*Thus, the codfish deposits 9,000,000 eggs at one time; the tench about 350,000; the perch, 300,000; the carp contains 50,000 eggs to every pound of weight; the pike, 40,000; the salmon, 25,000, &c.

species; but this will soon be rectified again, and man alone, with the powerful means at his disposal, has the power to destroy this order for ever and to his own great detriment.

But human influence itself varies considerably according to local conditions. In the oceans and large seas man cannot injure the spawning-places of those fish which deposit their spawn in the sea itself or at a great depth, as for instance, the cod, nor can he prevent the fish from reaching these places. He can neither destroy the spawn nor, as a general rule, catch those young fish which have not yet attained the age of maturity. These young fish escape and spread over the immense extent of the sea.

In rivers, lakes, and other limited sheets of water, the fish are brought within the reach of man's influence under very different conditions; here we find that the basis of a good system of pisciculture mentioned above is wanting either entirely or in part.

This fact is also established in Russia, not only with regard to the lakes, but also to the inland seas, such as the Caspian Sea and the Sea of Azov. The abundance of fish in these seas is truly astonishing, and surpasses everything which is known of the most celebrated fisheries of the ocean, such as the Newfoundland Bank,* the Dogger Bank, or the Westfiord in Norway. But this large number of fish depends to a great extent on man's action. In the Sea of Azov, the principal and almost only source of, what is there called the "white fish," (*Lucioperca sandra*, Cuv., *Leuciscus Heckelii*, Nordm., and *Cyprinus carpio*, L.,) is the delta of the Kauban, which combines all the most favorable conditions for spawning.

Throughout its whole extent enormous fisheries are carried on, the young fish are saved, and all the regulations tending to protect the circulation of fish in the net-work of lagoons, in the branches of the delta, and the bed of the river are carefully observed. If, however, this system of pisciculture at the mouths of the Kauban was not modified, it might have a bad influence, not only on the river-fisheries, but also on those of the Sea of Azov, on account of the transformation of the vast lagoons, where millions of fish spawn, into salty marshes. In the Volga and in the other rivers which fall into the Caspian Sea, the distribution of the water in the delta is not hindered in any way. The fishing of young fish by means of nets with narrow meshes is not in vogue; but, on the contrary, it is not very long since the whole space extending before the mouths of the Volga was encumbered by innumerable lines of fishing-apparatus, and the free circulation of the fish which had entered the river was hindered by the constant use of draw-nets, and by the river being filled with hooks, nets, leaps, and crawls. Consequently an insufficient number of fish was allowed to pass on to the spawning-places. The law of 1865, with its new regulations, has abolished this abuse. In the inland lakes of Russia, which cover a vast area in the northwest,

*The number of fish caught at Newfoundland is scarcely half that of the Caspian Sea.

especially in the shallow lakes, which are well known for their wealth of fish, the third condition of rational pisciculture mentioned above would often have been disregarded, *i. e.*, people would have fished the young fish before the age of maturity if nets with narrow meshes had not been prohibited.

2.—PISCICULTURE.

The decrease of fish in consequence of a bad and destructive system has attracted the attention of the governments, nearly all of whom devote more or less considerable sums to the encouragement and development of the fisheries, in order to diminish the destruction of fish by means of various protective measures. The decrease of the Russian fisheries has led the imperial ministry of domains to make a series of statistical researches with regard to the fisheries, with a view of throwing light on all the causes of this decrease. These researches, commenced in 1859 and finished in 1872, have been made in the Baltic, the Polar Sea, the White Sea, the Caspian Sea, the Black Sea, and the Sea of Azov, as well as in the more important lakes. The result of these investigations has served as a basis for the new legislation, and has led to administrative measures looking toward the protection and development of the fisheries.

In Russia, as well as in other countries, the government has been aided in its efforts by a new science, which in our days has become of the greatest importance as a branch of national industry. The labors of various distinguished scientists, who have devoted themselves to the study of icthyology, have led to interesting discoveries, several of which have proved of the greatest practical use. One of the most important among these last-mentioned discoveries is the artificial impregnation of spawn, which, as experience has shown, enables us to multiply the most valuable species in the most favorable localities, or to renew the wealth of fish which had been exhausted by a destructive system of fishing.

This discovery can be traced back to the middle of the eighteenth century, but its practical application as a branch of industry dates only thirty years back. The artificial raising of fish is in our days encouraged and aided by government, has developed extensively, and has rendered the most valuable services to the public well-being.

Pisciculture, or the art of propagating fish, was known to all civilized nations even in the most remote times. In the beginning, the following method was observed: At the spawning-season, fagots and branches were placed in the rivers and their tributaries, forming hedges, on which the fish deposited their roe as on a natural bottom. After the roe had been impregnated, it was gathered and taken to those places where one wanted to introduce fish or multiply them.

In the fifteenth century other methods of propagating fish were employed. Long wooden boxes were prepared, open at the top, and their straightest sides being composed of osier or reed trellis; at the bottom of these boxes a layer of fine sand was placed to serve as a receptacle for the roe; on this bottom the impregnated roe was placed, and the whole apparatus put in a place where the roe was exposed to a constant stream of fresh water. The development and hatching of the roe usually took place after three weeks, but a month was required for hatching all the eggs. This invention, which was a progressive step in the art of pisciculture, was improved in 1761 by a new hatching and incubating process. At that time artificial hatching-boxes were introduced, consisting of wooden boxes with perforated sides, in which branches were stuck. At the spawning-season, fish of both sexes were put in these boxes; thereupon the spawners were taken out, and the branches covered with the spawn were placed in boxes in such a manner as to avoid all contact between the eggs.

The discovery of artificial incubation belongs to a Frenchman, Dom Pinchon, (Bulletin of the Imperial Society of Acclimatization, 1854, p. 80,) and the construction of artificial spawning-boxes was invented by a Swede, (Lund, of Linköping;) the third and most important discovery, viz, that of artificial fecundation, was made by Ludwig Jacobi, a land-owner of Lippe-Detmold, (1711–'84,) who has left us an account describing his method very much in detail. This work may serve as a manual of practical pisciculture. The process of fecundation discovered by Jacobi, and known as "moist fecundation," is at the present day in vogue in most of the foreign establishments of pisciculture. In Russia the so-called process of "dry fecundation" is mostly employed. Both will be described below.

Jacobi's discovery was very little known till 1840, when a strong impetus was given to this industry in consequence of experiments in the artificial propagation of fish made in France by the fisherman Joseph Rémy and his friend Géhin. These experiments attracted the attention of the government, which shunned no expense and appropriated large sums for founding the establishment at Hüningen, placed at first under the direction of Berthot and Detzem, and finally confided to the care of the celebrated Coste. Through the influence of this establishment, which soon placed itself on a commercial footing and made it an object to sell fecundated eggs and fry, pisciculture developed very rapidly; and there is at this day scarcely a country where this industry is not known and does not attract the attention of land-owners. In Russia, the number of piscicultural establishments increases every day, in spite of the country's great wealth of fish.

Among these establishments, that of Nikolsky, located in the village of the same name, (province of Novgorod, district of Demyansk,) takes the first place, on account of its extent, its excellent technical arrangement, and, finally, by its method of fecundating eggs.

The establishment of Nikolsky belongs to the government, and is under the department of agriculture and rural industry.

In order to get a clear idea of all the operations of pisciculture, it will be necessary to consider each separately.

3.—SELECTION OF MALE AND FEMALE FISH.

For artificial fecundation it is indispensable to select fish which have attained their full reproductive maturity, and, as much as possible, at the very time when the spawn is ejected. This condition is very important; for fish, when it is at the natural height of its existence, is only with great difficulty kept in a condition favorable to reproduction. In order to follow the progressive maturation of the spawn of the female fish, so as to be able to use it at the proper time, one proceeds in the following manner: Several male and female fish of one species, or of two species if one wants to cross the breeds, are placed in reservoirs large enough to allow the fish to move freely. Every species is placed in a reservoir specially arranged in such a manner as to let each one have the temperature and the kind of water which it prefers. The trout, for instance, the various kinds of salmon, and the sturgeon, which propagate in running cold water, must be preserved in reservoirs fed from sources of fresh water; and if these cannot be had, the water must be changed frequently. Other species, such as the large pike, the carp, the perch, &c., which deposit their spawn in stagnant water, must be placed under similar conditions. In the establishment of Nikolsky the fish are preserved in ponds of running water, and a short time before the fecundation they are transferred to basins likewise supplied with running water, which are in the establishment itself.

When it is impossible to get living reproductive fish, one may use dead ones. Thus, during the first time of its existence, the establishment of Nikolsky had frequently to use, and nearly always with success, dead female fish which came from St. Petersburg. During the transportation, the genital aperture was closed with bandages, and the fish, wrapped up in hemp, were laid on their backs. It has been positively proved that the milt, as long as it is contained in the reproductive organs, preserves its prolific qualities for a very long time, and does not even suffer from cold, but if diluted with water it loses its strength very quickly. According to the testimony of several scientists, (Quatrefages,) every movement of the spermatozoids is stopped in milt which is diluted by water, under the most favorable conditions, in the pike in 8 minutes 50 seconds, with the roach in 3 minutes 10 seconds, in the carp in 3 minutes, and in the perch 2 minutes 40 seconds. As regards the spawn, we have not yet exact data as to how long a time it preserves the faculty of receiving the influence of the spermatozoids according to the temperature and the species.

When the eggs and the milt have attained their full maturity, which can be seen by certain external signs, (the swelling of the belly of the female and the enlargement of the genital opening of the male,) one proceeds to fecundate, which is done in two ways, according to the species of fish.

4.—THE FECUNDATION OF SPAWN.

Those fish which spawn on the sand, for instance, the trout, the lavaret, and the whole family of salmon, produce eggs which are easily separated, and which do not stick to other objects; but those species which deposit their spawn on aquatic plants—the carp, the pike, the perch, &c.—produce glutinous eggs, which adhere closely to the plants. The artificial fecundation of spawn of the first kind is also done in two ways: by the "moist" and by the "dry process." The "moist process," which is the more ancient, is followed in most foreign establishments of pisciculture; the "dry process," invented by the Russian pisciculturist, V. P. Vrasski, has been adopted in nearly all the Russian establishments, and has even been introduced into some foreign ones. The difference between the two methods is apparently very insignificant, but the results obtained by the "dry process" are by far the more advantageous. The "moist process" consists in taking a vessel of sandstone, of porcelain, or of wood, which must be perfectly clean, and constructed in such a manner as to have an opening equal in size to the bottom, or a little larger. The bottom must present an even surface, so that the eggs can be freely spread on it.

Enough water is poured into the vessel to cover the bottom to the height of two or three inches. The temperature of the water depends on the species of fish. The most convenient temperature for trout and salmon is from 39° F. to 50° F. The same temperature is good for those species which spawn in winter. For the pike it must be 41° F. to 50° F.; for the perch and the whole family of sturgeons, from 57° F. to 61° F.; and for those fish which spawn in summer from 68° F. to 77° F. In one word, it is necessary that the temperature of the water used for artificial fecundation is as near as possible like the average temperature in which the species lives that is to be operated upon. A difference of 6° to 8°, more or less, may stop the fecundation completely.

After this, one takes a female fish with the left hand and holds it perpendicularly above the vessel. The eggs generally fall into the vessel by their own weight, but if this is not the case one presses the belly of the fish gently with the forefinger of the right hand from top to bottom. After having gathered the spawn of the female in the vessel the milt is extracted from the body of the male fish in the same manner. When the water assumes a turbid and milky appearance, the spawn is mixed with the milt by means of a feather or the tail of the male fish. After 5 or 10 minutes the fecundation has operated; then the spawn is washed, the water in the vessel renewed several times, and the eggs placed in basins destined for their reception.

In order to fecundate spawn a peculiar apparatus is also used, consisting of a sieve with a metal tissue narrow enough not to let the eggs pass through, nor to allow them to be entangled in the meshes. The sieve is plunged into a vessel filled with water; its sides can be either of wood or metal; but if metal, they must be the same as the tissue, in order to avoid galvanic currents, which might hurt the spawn. This apparatus is convenient, for it dispenses with the necessity of changing the water containing the milt. After the fecundation, it runs out of itself through the holes of the sieve.

The "dry process" of fecundating spawn, invented by Mr. Vrasski, differs from the preceding by requiring two vessels, one for the spawn, which is put there without water, and the other for the milt, to which water is added to moisten the eggs. This method is extremely advantageous, for in using it scarcely 1 per cent. of the eggs escapes fecundation, while in the "moist method" 10 to 12 per cent. of the spawn may be lost. A little spoonful of milt is sufficient to fecundate 1,000 eggs. What has prevented the spreading of this method in other countries is the very improbable opinion that it is not applicable to fish which spawn in autumn or in winter, or at a low temperature in general. The principal conditions of success in the operations which we have just described are always: full maturity of the eggs and milt, a suitable temperature, and rapid execution.

The following is the method employed for fecundating glutinous eggs: It requires some bunches of aquatic plants, which are carefully washed, (*Ranunculus*, *Glyceria aquatica*, &c.,) a vessel of the shape and size of those used for the preceding operations, and a bucket. The manipulations require three persons. One of them holds the female fish, and extracts the spawn from it as described above, while the other extracts the milt from the male. The third person stirs the water with a bunch of plants, to favor the absorption. The spawn sticks to the plants, which are left for two or three minutes in the water containing the spermatozoids, so as to insure the fecundation of the eggs. Then the bunch of plants is washed with the spawn sticking to it, and put in the incubating-apparatus. As the fecundation of glutinous spawn requires the aid of several persons, and as, besides, the species of fish which have this spawn do not cost very much, it is usually multiplied in artificial incubating-apparatus, which has the advantage of avoiding almost entirely the loss of spawn, which, in the natural course of events, is inevitable. The construction of this apparatus varies very much. The simplest consists of two pieces of wood joined by several transverse pieces trimmed with aquatic plants. This apparatus is put in the water several weeks before the spawning-season; then it is taken out of the water. The plants are also taken out and placed with the eggs that are on them in the incubating-apparatus.

5.—THE INCUBATION OF SPAWN.

After the fecundated spawn has by itself become detached from the fecundating-boxes, it is put in an apparatus with compartments, where the incubation takes place. For this operation we may use a shovel, or we can also simply incline the vase which contains the spawn as near as possible to the bottom of the box into which it is to go, and pour it directly on this bottom. In this operation, care must be taken that the eggs do not lie on each other in layers. If among the eggs there is a little coagulated milt, it ought to be first washed out.

The apparatus for incubation and the hatching of young fish are very different. Every pisciculturist has his own models made to suit local convenience and his own individual ideas. The apparatus also varies according to the species of fish; the trout, the lavaret, the salmon, for instance, requiring cold running water, the incubating-apparatus must answer these conditions.

The article of this kind which is most used, on account of its answering its purpose best, is that of Coste. It is about 1½ feet long and 1½ broad and deep. The lid is formed of two parts, which open by hinges; these two panels have each a square opening, closed by a net-work of metal; the two straight sides of the box have also doors with openings like those of the lid, likewise furnished with the net-work of metal. Inside the box, at the ends and in the middle, there are cross-pieces of wood, on which other frames are placed, which are the most essential pieces of the apparatus; these frames consist of thin plates of glass in wooden frames; as many as four of these are placed on the same cross-pieces, and the fecundated spawn is put on these glass plates. On the bottom of the box sand is put, in case some eggs should escape through the small spaces between the strips of glass. This arrangement has the advantage, above all others, of being easily cleaned, and not bringing the spawn into immediate contact with the metallic sides, which might make it cold, might tear its delicate skin, and might jeopardize the life of these frail creatures.

For propagating fish on a large scale, the above-described apparatus, and other similar ones, are replaced by special incubating-canals, into which water is led from a spring or a pond. The arrangement of these canals is very simple; the water flows through a series of wooden or stone basins, covered with a net-work, to avoid all obstruction. In these basins the spawn is deposited on glass grates.

To incubate spawn in localities where there is no running water, other apparatus is used, the most common being that of Coste. This consists of a filtering-apparatus, which leads the water, through a pipe with a cock, into one or two basins made of sandstone or delf, on whose bottom gravel is placed; at the end of this basin the current divides into two, and, through small gutters, the water flows into troughs of sandstone, placed one over the other and parallel to each other; every one is provided with a slope or gutter on the side opposite to that where the water flows in. In this manner the water which comes from the delf basin and which flows through this whole system of basins forms an artificial brook. After having flowed through this whole apparatus, this water is collected in a special reservoir destined for the fish which have just been hatched, and from there it flows out.

During the period of incubation, the spawn requires the greatest care. The washing of the eggs immediately after the fecundation is rather difficult on account of their delicate outer skin, and this is precisely the time when they must be cleaned from all impurities; for the development of parasites is fatal to them at this time. The cleaning of the spawn is done by means of the down of a quill or with a soft brush; the spoiled eggs, which can easily be recognized by their pale-yellow color, are picked out with pincers similar to those used in anatomy, but differing in this respect that, instead of being denticulated, they terminate in a cavity which seizes the spoiled egg without endangering the others. If, on account of too strong a current of water, the spawn gets piled up in one place, which ought to be avoided, we must immediately diminish the current and spread the spawn evenly over the whole bottom; using for this small glass tubes, which are made in the following manner: take a tolerably large glass tube, blow a globe at one of its ends, and draw out the other end to a fine point; the large opening is closed by a stopper pierced lengthwise, through which a thin glass tube is passed. In using the tube, stop with the finger the thin end, and direct the the tube which passes through the stopper on the spawn, which, as soon as the finger is raised, passes rapidly at the same time with the water into the globe of the tube.

This instrument can be used not only for transporting spawn, but also for taking hold conveniently of small newly-hatched fishes.

6.—DEVELOPMENT OF THE EMBRYO AND THE HATCHING OF FISH.

The egg of a fish is composed of an inner bladder, which, as long as the egg is not put in the water, is in intimate contact with an outer covering. The inner bladder and its covering are joined by a thin channel, which, on the outside, opens by an orifice called micropyle, through which the spermatozoids enter the eggs. This opening was first discovered on the egg of a small bream (*Abramis blicca*, C.) by a Russian scientist, Mr. Baer, of the Imperial Academy of Sciences of St. Petersburg, and was next observed on the trout, the salmon, and the pike, &c. As soon as the egg has been brought in contact with milt diluted in water, or simply with pure water, the outer covering swells, through endosmosis, and separates from the coating of the inner utricle. During this absorption of water through the outer skins of the egg, it is absolutely necessary that a spermatozoid with fecundating liquid should, through the micropyle, pass inside the bladder. If this is not the case, no fecundation takes place. During the separation of the outer skin of the bladder, the channel intended to introduce the spermatozoid into the egg breaks, and communication between the bladder and the outside is interrupted; so that, if the spermatozoid has not had time enough to penetrate into the bladder, it cannot possibly get into it afterward, and the egg remains barren. These observations prove that it is very important that the spermatozoids of the milt, diluted in water, should be still in motion when the process of fecundation goes on, and should be able to take their course toward the opening of the channel and penetrate into the interior of the egg. We have seen that the movement of the spermatozoids cease very soon after diluting the milt with water; it is, therefore, highly important, for a successful fecundation, to dilute the milt and impregnate the spawn with the mixture as rapidly as possible. The inner bladder of the egg contains albumen and yolk; this latter is at first spread throughout the whole bladder, but after fecundation it all collects on one point and forms a separate yolk, (vitellus.) Then the yolk divides into two hemispheres, which again are divided; then the vitellus occupies two-thirds of the bladder. Finally it is possible to distinguish the head, the vertebral column, and the tail of the embryo; and about a month before being hatched the eyes can be distinguished in the shape of two black spots. In the lavaret they can already be seen in January.

The skin of the egg is soft before being fecundated, but after fecundation it becomes thicker and so hard that it is almost impossible to crush the egg between the fingers. Toward the end of the development of the egg, the skin secretes a substance destined for forming the hard portions of the embryo, and then it becomes transparent, fine, like the web of a spider, and so delicate, that at the least outside pressure it tears on all sides.

After the fish has come out, it carries with it the umbilical bag containing a supply of nutritive substance, which is absorbed by means of blood-vessels spreading all through the bag. After all has been absorbed, the young being has the perfect form of a fish, and is called fry, ("alevin;") it now requires outside food.

The hatching of fish is not done all at once, but gradually, under the influence of certain external causes, such as the temperature of the water, the quantity of oxygen contained in it, &c. It is necessary to watch the temperature and purity of the water very carefully. Dust floating in the air over the water, and various impurities which fall in the water and mix at the bottom of the basins with innumerable microscopic pieces of vegetable fiber, form tufts, in which, if the temperature of the water is higher than 50° Fahr., myriads of infusoria develop. These tufts get into the mouths of the young fish, and, being ejected together with the water, obstruct the gills and produce suffocation.

After having absorbed the umbilical bag, the fish seeks other food. The possibility of satisfying this want during the first time has a decided influence on the further development. The young fish shows by its first movements an innate tendency to seize food, just as mammalia immediately after their birth instinctively seek the breast which is to give them food. As regards the most suitable food for young fish, the trout and the salmon family chiefly feed on animate matter, *e. g.*, on the spawn or the young of the *Cyprinus alburnus*, Cuv.; on the *Cyprinus leuciscus*, Cuv., (or *Aspius alburnus*, Agass.;) or on fish of the species

Coregonus, Cuv. The young lavarets first feed on insects; but, arrived at a certain age, they also eat the spawn and young of the roach and the ablet. Young trout and young salmon require running water where insects cannot live, while the young of the lavaret requires more stagnant water, because the insects which form his food can there live and multiply. The spawn of the ablet and other small fish which form the food of the trout, the salmon, and the lavaret is obtained in every establishment of pisciculture by means of artificial spawning. As the young fish during the first time of their existence, if they were placed in ponds and reservoirs to increase, would every minute meet with innumerable and unavoidable dangers, (fish, insects, &c.,) and would perish uselessly, one ought, before transferring the young fish to natural reservoirs, to raise them in fish-ponds, which are true nurseries of fish. According to the extent of the pisciculturist's business, these fish-ponds may be merely boxes or ponds, or, in short, any reservoir where the fish can be placed under conditions that are favorable to its development, and where it can be protected against its various enemies while it is still too feeble to defend itself.

7.—TRANSPORTATION OF SPAWN.

The most common way of transporting spawn longer or shorter distances is the following: A wooden pail is used, the bottom and sides of which are covered with a damp cloth, which separates the layers of eggs; this cloth is always kept damp, and in its stead moss or certain aquatic plants may be used, between which the spawn is spread. In doing this, care should be taken that the eggs do not press against each other, and that the pressure of the upper layers does not injure the lower ones. The establishment of Nikolsky sends fecundated spawn in this manner through the whole of Russia. The glutinous spawn is transported with the plants to which it adheres in glass bottles, filled to three-fourths of their capacity with water, or in baskets and boxes wrapped up in damp cloths. The vessels in which fecundated spawn is transported, especially long distances, must always be wrapped in substances which are as little as possible conductors of heat; moss, felt, etc. For the different kinds of salmon the temperature must be 32° to 50° Fahr., while for other fish it must be higher.

Whatever means of transportation be employed, spawn must not be shipped immediately after fecundation, as experience has shown that the best time for this is when the embryo has reached that stage of its development when two black dots can be observed in the place of the eyes.

The transportation of fish depends on its age; the younger it is the easier it can be shipped. Young fish scarcely hatched are sent in glass vessels, the water on which must be changed every two or three hours. This frequent change of water may, however, be avoided by passing a current of fresh air through it, which is done by means of a tube dipped into the water of the vessel.

Spring and autumn are the seasons most favorable for transporting fish. In the summer they are sent by night, being careful to keep the water constantly in motion, even when a halt is made. During long journeys the water in the vessels is renewed from time to time, and air is introduced by means of bellows and a tin tube.

8.—PISCICULTURAL ESTABLISHMENT AT NIKOLSKY.

After having spoken of the technical part of pisciculture, we will give a detailed description of the arrangement and work of one of the largest establishments of this kind not only in Russia but in Europe. The work done at the establishment of Nikolsky will give us a great deal of information and furnish many instructive examples. This establishment is located almost on the boundary-line of the districts of Démyansk and of Valdaï, (province of Novogorod,) on the high-road, 77 versts (about 48 miles) from the Valdaï station on the Nicholas Railroad. The highest elevation of the Alaoune Mountains is in the districts of Valdaï and Démyansk, and these districts are, therefore, crossed in all directions by high hills. The valleys formed by these hills inclose a large number of lakes, mostly fed by small and rapidly-flowing streams. The water of the lakes is pure and cold. This locality, as will be seen, combines many conditions favorable to pisciculture, especially for the breeding of valuable species, such as the trout. M. Vrasski, a rich land-owner of this province, has made use of these favorable circumstances to found his establishment. After having examined the work done in France by Rémy and Gehin, and after having studied the theoretical part of pisciculture, Mr. Vrasski, in the spring of 1854, made his first experiments on the spawn of eelpout and "jaculus," and finally on that of the trout. The food of the hatched fish presented the greatest difficulties. Meat chopped fine, recommended by some foreign pisciculturists, was unsuitable, and inconvenient in various ways. The food of young trout during their first stage consists of aquatic insects, and, from an inborn instinct, they did not seize the pieces of meat except during their fall to the bottom, but never touched them when motionless. The meat consequently began to decompose, changed the character of the water, and the fish died. Mr. Vrasski then thought of feeding the young trout with the insects which swarm in stagnant water, and obtained favorable results. The trout produced by him in 1855 measured, two years later, 22 centimeters, and in some the milt was matured. After a long series of experiments, Mr. Vrasski achieved the most brilliant results in fecundating spawn, and his experiments led him to the discovery of a new method.

In order to fecundate eggs, it is necessary, as we have said above, that the spermatozoids contained in the fecundating-liquid of the male fish should penetrate into the eggs laid by the female. For this purpose it was necessary, according to the manual which Mr. Vrasski followed, to press the spawn from the females into a vessel filled with water, to place the milt of the males in another vessel, and, after having diluted the fecundating-liquid, pour it into the vessel containing the eggs. Mr. Vrassky had meanwhile observed that fecundation was less successful if there was any long interval between the time of extracting the spawn from the female and the time of its coming in contact with the milt. If this interval exceeded ten minutes, fecundation failed almost entirely. By numerous microscopic observations made with Dr. Knoch, a learned embryologist, Mr. Vrasski convinced himself that, in coming in contact with water, the spawn absorbs this liquid, and that the process of absorption takes no longer than half an hour; but that spawn placed in a vessel in a dry state remains a long time without changing, and without losing its property of absorbing water and of receiving spermatozoids. The spermatozoids of the milt, when brought in contact with water, make violent and rapid movements, which, however, last only one and a half or two minutes, while milt kept dry in a vessel or on a glass plate preserves its qualities for several hours, during which time the spermatozoids show under the microscope the same rapid movements which they make in water the moment they leave the body of the fish. In making experiments with the river-perch and the *Acerina vulgaris*, C., on milt that had not yet reached its mature state, he found that some drops of milt kept in a perfectly dry and well-closed cylinder had not lost their original qualities, even after six days in the ordinary temperature of a room. By combining these data with the circumstance that spawn and milt when taken from the bodies of fish do not come out all at once, but run out gradually and slowly, Mr. Vrassky arrived at the conclusion that, by putting the spawn and the milt immediately in water, the larger portion of the eggs have time enough to get completely soaked, and that the majority of the spermatozoids lose their movements before the pisciculturist has time to mix the prolific water with the spawn. Then Mr. Vrasski commenced to put spawn and milt in vessels without water, and to pour the fecundating-liquid over the eggs immediately after having diluted the milt. The results were entirely satisfactory, for not a single egg remained barren.

After having achieved such a brilliant success in fecundating spawn, Mr. Vrasski associated himself with two others, with the view of founding an establishment on a large scale. For this purpose he used the Pestooka, a river which joins Lake Pestow (1¾ miles long) and Lake Vélio, (about 4⅔ miles long;) with the water of this river he fed several basins and fish-ponds, where the water could be made to rise or fall by means of water-gates placed farther up the river at the place where it leaves Lake Pestow.

The building, built of wood, on stone foundations, is 12 sagenes (84 feet) long, and 6 sagenes (42 feet) broad.

The water of a pond is conducted into the establishment by means of a subterranean pipe, and flows into a tub called a "leveller;" this is made of two joists, is 7 feet high, and 4 feet 8 inches long and broad. From this reservoir water is distributed through the whole building. In the middle of the building there is a large basin fed with running water, which serves as a fish-pond for the male propagators and the females. It is made of planks, 49 feet long and 9 feet 4 inches broad; it is divided into several compartments, into which propagating fish of every kind are placed separately during the period of fecundation.

Parallel to this fish-pond there are, on every side, eight smaller basins, made of flagstones and supported by brick arches; each of these basins is 23 feet 4 inches long, 3 feet 6 inches broad, and 10½ inches deep. A pipe coming out from the bottom of each of these basins feeds them with filtered water, which is kept ⅞ of an inch high; after having flowed through these basins, it flows out through a common outlet-pipe. The water of these basins is so pure that it is possible to discern the smallest straw at the bottom. In these basins not only the fecundated spawn is kept placed in small square troughs, but also the young fishes, which, till the time of their being placed in the lakes and ponds, are there fed with larvæ of insects and with young ablets, which are expressly raised in the establishment for this purpose. On every side of the "leveller" there are two square boxes for filtering water through layers of sand and flint stones; from these boxes the water passes into a third filter, and flows into the boxes where the fecundated eggs are washed.

For raising fish the establishment has, besides the lakes and the river, five ponds with running water, placed one higher than the other. There the young fish which have reached a certain degree of development are transferred from the basins in the building; there, also, the propagating fish are kept. The development of embryo is entirely successful; and this result is due as much to the "dry process" of fecundation as to the arrangement of the boxes with compartments, and finally to the low temperature of the water (35° F.) in which the eggs are developed. In other countries the eggs of trout are kept in a temperature several degrees higher than that of the water in the Nikolsky establishment, which induces the development of plants and minute animals, which are injurious to the eggs. At Nikolsky the sand (which has been previously washed in boiling water to destroy all animal and vegetable germs) and the eggs are five weeks after fecundation as clean as at the time they were deposited, while in foreign establishments they are obliged almost constantly to clean them from the spawn of parasitical plants and animals. At Nikolsky hatching goes on slower than in foreign establishments, which is but the natural result of the low temperature of the water; but the slow development of the spawn has this advantage, that the embryo grows more regularly, and that the young come forth precisely at the time when insect-larvæ abound most, so that they are sure of their food. The trout and the salmon generally spawn in November, and thus in foreign establishments, at the comparatively high temperature of 43° Fahr., the young fish develop and require animal food as early as February, a season of the year at which it is impossible to get insect-larvæ; it is therefore necessary to feed the fish on chopped meat, which, besides being expensive, changes the nature of the water and occasions a loss of fish. In our establishment, however, the development progresses more slowly, so that the young fish, which at first requires no food (the umbilical bag, as we have said before, is during this first stage of development absorbed by it,) is hatched in April, and becomes a young fish in the middle of May, when a large variety and abundance of suitable food can be found in every sheet of water. This food consists of living aquatic animals and insect-larvæ, which are gathered with muslin nets. At the end of May the young of the ablet, (*Cyprinus alburnus*, L.,) taken immediately after being hatched, are added to this food.

During the period of raising the young fish in the establishment, special care must be taken to prevent the drowsiness or sleep of the young fish. In a low temperature everything works well, but as soon as the temperature of the water is elevated, the young fish show a certain restlessness in their movements; they gradually seek that part of the apparatus which receives the water fresh from the feed-pipe, and there they gather in compact masses; their respiration is accelerated, the mouth remains open, and the gills move with an effort; then the tail and head grow pale, and finally the fish dies. This sickness increases in proportion to the heat of the water; and the more sudden the transition from cold to hot the quicker does the young fish die. This circumstance is explained in the following manner: Water, like all liquids, has the property of absorbing gases. The quantity thus absorbed increases when the temperature gets lower, and is less when the water is hotter. This property of water is especially important with regard to oxygen, which is one of the elements of the air, and which can continually dissolve in water. The absorption of oxygen by water has an immense influence on the life of fish. The young fish through its gills is constantly inhaling oxygen contained in the water, which passes into its mouth and decomposes its blood. At the same time it ejects with the water carbonic acid, which is a superabundant element in its organization. If the water contains less oxygen than is required to oxidize the blood, the gills change their lamellæ, and their fringes agglutinate, decompose, are covered with parasites, and the want of oxygen necessarily brings about the death of the fish. The necessity of oxygen forces the young fish toward the place where the water has not yet become saturated with carbonic acid, viz, toward the opening through which the compartment is fed with water. Each fish seeks to drive away the other to get sooner to the fresh water; the feebler ones have to give way, become still feebler, and perish on account of insufficient respiration. To avoid this suffocation of the young fish, the following methods are employed at Nikolsky:

1. Through the box, with compartments at a certain distance from each other, and at a convenient height above the boxes, zinc pipes are placed, pierced by straight openings, joined to each other, and at their ends to other larger pipes. Some of the water coming from the filters in this way flows out into the box, through the openings of the pipes, in the shape of a fine rain. All these small drops of water pass through the air during their fall and become saturated with oxygen; in striking the surface of the water, they refresh it with diminutive drops, which, rising and falling, increase the absorption of oxygen.

2. To renew in the water the oxygen destroyed by the respiration of the fish, air is also blown into it by means of bellows. This method is particularly useful, because the air, entering the water from above and below, only passes through it slowly, being retarded in its progress by the pressure of the upper layers. Moreover, the contact between the water and the air is more complete, and is brought about on comparatively larger surfaces, which, of course, causes a greater absorption of oxygen. In following this method, care should be taken to blow air into the water for a tolerably long time; and if it is impossible to do it continually, it should at least be done in such a manner as to let this aerating process go on, not only in one place of the box, but throughout its whole extent.

3. As, independent of the respiration of the young fish, the decrease of oxygen is brought about by heightening the temperature, this inconvenience is remedied by putting ice in the filters or in the boxes, the ice being put in special receptacles, so that it cannot communicate its impurities to the water.

Jointly with this method, the following is also employed: as soon as the temperature of the water commences to rise, the embryo, even if it should not yet have reached the state of young fish, is transferred to the ponds, where, as much as possible, it is placed in the bed of the Pestooka River, which flows through all these ponds.

The extent of the establishment enables it to fecundate annually 5,000,000 lavaret* eggs, 2,000,000 trout eggs, and more than 1,000,000 salmon eggs. The basins and nurseries are large enough to raise and feed every year more than 600,000 fish. Besides this, the establishment can prepare for the trade about 1,000,000 eggs which have reached that stage of their development when the eyes of the embryo can be discerned through the skin.

The establishment of Nikolsky, for the foundation of which, independent of the personal funds of the founder, the government has granted a subsidy of 30,000 rubles, ($21,000 gold,) was, till the year 1868, under the direction of a society of pisciculturists, but since that year it has become the property of the national treasury, and is at present under the department of agriculture and rural industry. As long as it was in the hands of private individuals, its aim was almost

* White-fish, (*Coregonus.*)

exclusively a commercial one; *i. e.*, the sale of fish raised in the establishment, particularly to the two capitals, Moscow and St. Petersburg. But after it became the property of the government, the establishment has in pisciculture assumed the same place as a model-farm in agriculture, or an acclimatizing-garden in horticulture.

Three methods are known of própagating new species of fish:

1. The transportation of grown male and female fish to a certain given locality. By this means salmon and salmon-trout have, in 1852, been introduced in Lake Peipus; but by this means but a very limited number of fish can be propagated in a river or in a lake, as, on account of the vast extent of these natural reservoirs, there is very little chance of the two sexes meeting at the proper season and in a favorable place, so that this method is far from insuring the multiplying of the species.

2. The transportation of fecundated spawn by natural means from one reservoir to another. This method is often followed, and in many cases it leads to good results; but it could not be applied under all circumstances, for many fish spawn at a great depth, or in inaccessible places.

3. The transportation of spawn that has been fecundated artificially. This method answers the purpose best.

The establishment of Nikolsky is in a locality which communicates with the basins of the Volga and the Ladoga. It is only one verst (five-eighths of a mile) from Lake Vélio, which, through small rivers and a lake, communicates with Lake Ilmen. These rivers are the Yavon, the Polla, and Lake Seligher, which, through the Selijarooka River, has a communication of about sixty miles in length with the Volga. Thus the establishment combines the climatic conditions of the basins of the Volga and the Ladoga—conditions which are very favorable to the acclimatization of fish from one basin to the other. The common lavaret, for instance, does not exist in the basin of the Volga, while it abounds in that of the Ladoga; the latter, on the contrary, has no sturgeon, while these are very common in the Volga. The establishment has, therefore, made it its object to spread in the basins of Russia those species of fish which are wanting, but which, as far as the quality of the water and the climate are concerned, might be introduced there, and which, by their price, might offer great advantages to fishing-industry. With this view, the introduction of lavarets into the basin of the Volga was undertaken. Numerous species of this fish, as we have said above, are found in the basin of the Ladoga, while in that of the Volga only a single one is found, the large and excellent species of white lavaret, called in Russian "Bélorybitsa." As the place of transportation, Lake Seligher has been selected, where every year several thousand lavarets one and a half vershock to three vershocks (two and a half to five inches) in length are let loose.

The success of this attempt can no longer be doubted, considering that the fish loosened in the Volga constitute the second generation of lavarets bred and raised in the establishment and completely acclimatized in a locality midways between the basin of the Ladoga (the home of these species) and that of the Volga; so that these fish in being transported to the latter do not undergo any material change of natural influences.

Among the species of the sturgeon kind it is principally the sterlet (*Acipenser ruthenus*, L.) whose artificial breeding has long since attracted the attention of Russian and foreign pisciculturists. The attempts at artificial fecundation of this valuable species made in Russia in 1869 led to excellent results, and during the course of the year 1870 the ministry of domains was able, at the request of the British government, to send several thousand sterlet-eggs to Scotland; these eggs arrived safely at their destination, packed in tinned copper vessels, and were placed in the rivers of that country.

Since 1870 the piscicultural establishment of Nikolsky has made experiments in multiplying sterlets in lakes and ponds. The former experiments in multiplying these fish by letting grown fish loose had always failed. The fish lived, grew, but they did not increase; which circumstance induced the erroneous opinion that it is absolutely impossible to multiply sterlets in ponds and lakes. The cause of this failure not having as yet been studied exactly, the belief may be allowed that this opinion does not rest on a solid basis. Of all piscicultural establishments, that of Nikolsky, being in Russia, the home of the sterlet, has the exclusive opportunity of studying and of solving definitely the problem of multiplying this fish in lakes and ponds; the experiments which have been commenced for this purpose are still going on and will be continued till definite results have been obtained.

In 1871 the establishment of Nikolsky commenced to sell fecundated spawn and hatched fish with the view of giving private individuals an opportunity of introducing valuable species at a moderate price, into their own waters. The spawn is delivered by the establishment in that stage of development when the eyes can be discerned through the skin. From the time that the establishment has advertised the sale of spawn and of hatched fish, it has received orders from different parts of the empire amounting to several tens of thousands of eggs, as well as of hatched fish of the trout, the salmon, and the lavaret, delivered at a fixed price; besides this, about 2,000 eggs are sent *gratis* every day to the Academy of Forestry and Agriculture at Pétrovsky, near Moscow. Spawn is sent to the most remote provinces of the empire, for instance, to the province of Stavropol, without undergoing the slightest change. It is remarkable that the spawn sent to the Academy of Pétrovsky when the cold was severe, froze during the journey in spite of its being covered, and thawed in cold water on its arrival at Moscow, has not suffered in the least, and that of 2,000 eggs only ten were not hatched. Spawn is transported partly as merchandise by express train, and partly, under the authority of the minister of the interior in the mail-cars.

The fish are sold from the age of six weeks to two years; the prices fixed for spawn and fish are the following:

	Gold.
1,000 trout or lavaret* eggs, fecundated, and having reached the stage where the eyes can be discerned	$2 10
100 young trout, six weeks old and able to seek their own food	2 10
100 trout or lavaret, three months old	3 50
100 trout or lavaret, six months old	5 60
100 trout or lavaret, one year old	10 50
100 trout, a year and a half old	17 50
100 lavaret, a year and a half old	14 00
100 trout, two years old	24 50
100 lavaret, two years old	17 50
100 trout, two years and a half old	31 50
100 trout, three years old	38 50

The sale takes place at the following dates: Eggs, from the 1st to the 13th of January to 15th and 27th of March; hatched fish, from 1st to 13th March to 1st and 19th of June; trout and lavaret, one month old, in September and October.

9.—PISCICULTURAL ESTABLISHMENT AT SUWALKI.

We think it our duty to mention, after the piscicultural establishment of Nikolsky, another establishment, founded by the government in the province of Suwalki, with the view of increasing the revenue from local fisheries.

This establishment is located in the water system of Lake Wiczera, on the Ganeza River, which, near the town of Suwalki, flows through Lake Wiczera and falls into the Augustovo Canal. It commenced operations in 1860, devoting itself chiefly to the breeding of trout, salmon, and the two very rare species of lavaret found in these lakes; the "sèja," (*Coregonus marœna,*) and the "seliava," (*Coregonus albula,*) species which are not so rare in the countries bordering this province on the west.

The fish raised in the establishment either from spawn artificially fecundated received from other parts, or from spawn fecundated at the establishment, have been placed in the lake. The species to which they belonged have in this manner been introduced in sixteen lakes in the province of Suwalki belonging to the government. The labors of the establishment have exercised a favorable influence on the revenue derived from the fisheries on Lake Wiczera, so that the revenue from fisheries, which in 1860 brought 120 rubles ($84) per annum, has risen to 700 rubles ($490) in 1869, while the amount of annual revenue from the Lake of Augustovsky has risen from 1,600 rubles to 3,300 rubles, ($1,120 to $2,310.)

The lavaret has been propagated to such an extent that at present this fish is sold smoked on the Warsaw markets, which never was the

* White-fish, (*Coregonus.*)

case in former times. This fish, entirely unknown to the trade, was formerly only found in very insignificant numbers in Lake Wygri.

Among the private establishments we ought not to pass in silence that of Senator Zeumern located about 22 miles from St. Petersburg, which chiefly raises trout.

10.—PISCICULTURE IN FINLAND.

In Finland, pisciculture has assumed vast dimensions; there are at present in that country more than ten large establishments, which propagate valuable species of fish, such as the trout, the salmon, and the lavaret.

The man who has done most for pisciculture in Finland is the famous pisciculturist Holmberg, who, in 1862, became inspector of pisciculture in that country. He has personally contributed toward the foundation of the following establishments: at Stokfors (province of Wyborg) on the coast of the Gulf of Finland; on the branch of the Kioùmène River called Souttè; in the town of Tammerfors, where the establishment is fed from the falls of the same name; and at Aborfors on a branch of the Kioùmène River. This last-mentioned establishment propagates the salmon of the sea.

Through the active and enlightened assistance of Mr. Holmberg, the establishments of Swarta (Province of Newland) have been founded on the river of the same name. There they principally propagate the lavaret, the salmon, the trout, (*Salmo fario, L.*,) and the carp. It has been observed at this establishment that a salmon which measured 14½ inches and weighed nearly 1½ pounds in August, 1863, had in the month of October attained the weight of 1¾ pounds and the length of 17 inches. It had, therefore, in two months grown in length 2½ inches, and in weight more than ¼ pound. The carp intended for propagating have been brought from Lubeck in 1861. We may also mention the piscicultural establishment of Kroneburg, on Lake Ladoga. Those of Kioùmène, located at several points on the river of the same name, near the Gulf of Finland, that of Keksholm, on the Island of Sikkolauter, between the sources of Wokcha and the hills of Keksholm, &c. The fecundation of spawn in these Finland establishments has at first been carried on according to the "moist method" introduced there from Norway; but since 1862 the "dry method," invented by Mr. Vrasski, has been followed with great success.

Regarding the raising of young fish, we must remark, that in the larger number of piscicultural establishments in Finland the young fish remains only for a very short time in the building, and as soon as it has absorbed the umbilical bag it is let loose in the rivers.

As food, the young of the *Aspius alburnus*, Agass., are used, raised specially for this purpose; the larvæ and cocoon of the viviparous fly, (*Sarcophaga carnaria* Cuv. *Musca carnaria*, L.) and finally flesh of fish or meat chopped fine.

The salmon are particularly fond of quite young ablets; thus in the establishment of Swarta it has been observed that young salmon would in a few moments devour seven or eight little ablets.

Independent of the establishments which are employed in the propagation of "winter fish," there are in Finland many other establishments which raise the several kinds of "summer fish," the perch, the bream, &c. These establishments are found throughout the whole interior of the country, and their number increases every day, for they require neither any very great expense for starting, nor much care in working them.

C.—REPORT ON THE STATE OF PISCICULTURE IN FRANCE AND THE NEIGHBORING COUNTRIES.

BY M. BOUCHON-BRANDELY, *Assistant Secretary of the College of France.*

[Report to the minister of public works in 1873, translated from the French by H. Jacobson.]

1.—INTRODUCTORY REMARKS.

Pisciculture, which, in the College of France, has developed so rapidly under the direction of our celebrated physiologist, M. Coste, and of M. S. Chantran, is a science which ought to have a place in the system of instruction.

The mission which you have confided to me has enabled me to trace the outlines of an economical and practical treatise, which I shall soon have the honor to present to your excellency in complete shape.

We know from the reports of Mr. Ashworth how much Great Britain has profited by the national enterprise of M. Coste, since as early as 1860 the salmon-fisheries of Scotland and Ireland alone amounted to more than £800,000. Germany, Belgium, and Holland have likewise profited from our establishment at Hüningen, which has been organized under the direction of M. Coste, thus putting to practical use a discovery in physiology.

The countries which I have visited, Switzerland, Austria, Italy, all equally show signs of remarkable progress, which is due to the lead taken by France.

It would be very much out of place in our day to trace to the ancient inhabitants of China and India discoveries to which they were perfect strangers. We must not confound pisciculture, properly so called, with the art of fishing, which at all times and in all countries of the globe has been held in great honor; and Rémy has certainly not got his idea of fecundating spawn artificially from the annals of the celestial empire. Nor had the College of France to look for advice to India or China in making its first scientific attempts, which have been crowned with such signal success. Not much time was consumed in developing this first great idea, and Hüningen was established. The favorable results which had been obtained are at the present day in danger of being lost.

The idea has been broached of replacing Hüningen by an establishment in France organized on the same plan, but your excellency will see from the concluding part of my report that, in order to meet satisfactorily the demands of pisciculture, you ought to increase the number of establishments by diminishing the importance of each one.

Professor Joly, of Toulouse, has, in 1866, published a report on river pisciculture in France, which gave rise to the brightest hopes. The disasters which have fallen on our unfortunate country have again made all this questionable; but if we have lost Hüningen, the laboratory of the College of France still exists and continues the work commenced at another period under such brilliant auspices. From that institution comes the impetus, and I had new proof of this during the tour which I have just made through Switzerland, Austria, and Italy.

2.—SWITZERLAND.

Switzerland, more than many other countries, has profited from the new science of pisciculture, and the progress made in that country deserves to be widely known. The federal government, the cantonal governments, and private individuals saw that this science contained a new and fruitful source of wealth for a country whose waters are of such excellent quality and are so well distributed. Pisciculture has made Switzerland its adopted country. Establishments have been founded by cantons and by private individuals. To these last mentioned the State granted great privileges, and the fishing-laws protect them, and at the same time favor their experiments.

In Switzerland, as in France, the number of fish in rivers and lakes decreased rapidly, and in spite of their great wealth of fish it was high time to remedy this matter. Artificial pisciculture has supplied the remedy, and at present the fish increase as fast as they are destroyed.

Before reviewing the establishments which I have visited, I must mention a fact selected from a large number: the inhabitants of the village of Vallorbe, near Jougne, about twenty years ago lived from the fisheries in the river Orbe. By exhausting this river, which was especially rich in the salmon kind, without ever replenishing it, the fishers and their families were reduced to absolute want. The observations of Rémy, confirmed by experiments made at the College of France, reached the ears of the schoolmaster of the village; he first studied pisciculture theoretically, and finally attempted some experiments, which were crowned with success. The inhabitants of the village anxiously but somewhat incredulously followed the different phases of the artificial hatching of fish-eggs, which went on under the most favorable conditions. The village became interested in these experiments, and several hundred francs were annually appropriated for aiding the schoolmaster in his enterprise. At the present day the river swarms with fish, and according to the official report there are eighty families which live entirely off the fisheries.

The first establishment which we visited in Switzerland is that of Dr. Vouga, a learned and conscientious man. Every pisciculturist knows Dr. Vouga by reputation, and at the last scientific congress held at Lausanne a conference regarding his work was held, and was greatly appreciated by scientists. His method of artificial fecundation consists in placing the eggs in a vessel without water and then pouring in the milt. Of 6,000 eggs which he thus fecundated last year not one proved a failure. The establishment of Dr. Vouga has not yet been entirely organized, but it has already rendered excellent service, and the river Reuss, which is farmed by him, is now, through his exertions, completely stocked with fish.

Mr. Hasler, of Interlachen, is an intelligent and practical man, who by himself has learned all the secrets of pisciculture; he makes many experiments on the nature of the water and its influence on the development of fish. His establishment is fed from a very pure spring and from the Lutschine, a stream formed by the glaciers of the Jungfrau. Mr. Hasler has carried on pisciculture for four years only, and he possesses the most remarkable specimens of fish, which he has bred and raised artificially. The question of food constantly occupies his attention, and we believe that the system he has adopted, and which consists in putting the young fish in water which was but seldom renewed, allowing the infusoriæ to develop, will prove very satisfactory in the end.

The cantonal establishment at Zurich, located at Meilen, has been in operation for sixteen years; it is destined to replenish the Lake of Zurich from the waters which feed it, and to improve the species found in that part of Switzerland. The government annually appropriates the sum of 3,000 francs for this establishment.

Every year, in the month of October, the government orders the fishers to gather, at the sources of the Rhine, salmon destined for reproduction. These salmon are placed five in a cask filled with water and capable of holding from 400 to 500 liters, (87½ to 109 gallons.) They are sent to Zurich by railroad, and from there to Meilen by steamer. During the journey the water is renewed three times. At Meilen they are placed in water to await the time of maturity.

In the reservoirs of the establishment very fine lake-trout are kept, with which a cross-breed is produced. The object of this crossing is to produce a variety of the salmon kind, having the shape and quality of the salmon, and preserving at the same time the habits of the trout, *i. e.*, it is desired to produce a stationary salmon, staying in the waters of the lake, without feeling the necessity of going into the sea. It is believed that this result has been *obtained*, and it is even thought that this cross-breed is capable of reproduction. The person who is at the head of this establishment has assured us that this is the case, and the experience of Mr. Samuel Chantran, of the College of France, has proved it. The specimens shown to us were, without a single exception, very fine, and even if this were the only result obtained, it would be a great step toward improving the species.

A million of young fish are every year thrown into the lake of Zurich, which, without this precaution, would not contain a single trout on account of the rapid increase of fish of prey, especially of pike.

The establishment of Mr. Massart, of Berne, is one of the most complete and best organized which I have seen, and shows the great experience of its proprietor in pisciculture. It is located on the banks of the river Aar, seven or eight kilometers (4½ to 5 miles) from Berne. The water which feeds the basins is of two kinds—spring water and river water; during summer the latter is used, because it is more abundant and carries with it more alimentary matter than spring water; it is besides just as fresh at this time of the year on account of the snow melting in the mountains, which are very near. Spring water is used during winter and for hatching. The basins of the establishment are small but deep; the largest only measures 80 square meters and has a depth of perhaps 2 meters; they are dug into the ground.

Mr. Massart, like all pisciculturists who are obliged to experiment in order to learn, has, in the beginning, met with many failures; but by perseverance he has succeeded in averting the misfortunes which seemed especially to strike the young generations. It is well known that the most critical moment in breeding fish is that which follows immediately after the absorption of the umbilical bag. During this period, which lasts at least four to five months, the young fish are frequently attacked by what is commonly called malady of the gills, and at this moment the choice of food is a matter of the greatest importance.

Mr. Massart places his young salmon, two weeks before the absorption takes place, into a large basin, which is not very deep, and but sparingly fed with water, and which remains almost entirely dry for seven or eight months of the year. During this time the infusoriæ have time to develop, and when the young fish are placed in the basin they there find a food which is suitable for their age.

Mr. Massart actually raises 20,000 trout every year, and besides furnishes the Prussian administration at Hüningen with millions of eggs, which are from there sent to different parts of Europe.

Large numbers of white-fish live with the salmon, and serve them as food. Mr. Massart adds to this boiled corn made into a paste. It will scarcely be necessary to say that pike or perch, as soon as they show themselves in the waters of the establishment, are immediately killed.

This piscicultural establishment is destined to a great development, and will render great service to the city of Berne. The government has given Mr. Massart the right of fishing at every season of the year, and keeps a close watch over his property. A neighbor, who was convicted of having taken two trout out of his basins, was arrested by the cantonal police, and had to pay very dear for this transgression.

Since that time Mr. Massart has had nothing to fear from trespassers. Fishers who catch fish which have not yet attained their regular size must throw them into the basins of the establishment if they are alive; if dead, they are confiscated and given as food to other fish.

Mr. Massart has also made interesting experiments with a view of determining the influence of different waters on the development of fish. From the specimens which can be seen with him, one arrives at the conclusion that rapidity of current and fresh water are essential conditions for raising salmon.

In concluding our Swiss review we must briefly mention the establishment of M. de Loës, at Aigle, in the canton of Vaud, and the measures which the cantonal government has taken for replenishing their rivers.

M. de Loës, like Dr. Vouga, is a corresponding member of the Acclimatization Society. His experience is very valuable, and the federal government has understood this so well that it has intrusted to M. de Loës the entire administration of pisciculture in the canton; and, thanks to his exertions, there will soon be no lack of fish in the lake of Geneva, in the river Rhone, and the rivers of the canton.

At the request of M. de Loës, the government has established two fish-ponds at Lay, near the banks of the Rhone, where those fish are kept in reserve which are destined for reproduction. A government commissioner has to examine the fishing, and retains those fish which are to form part of this reserve. As fishing in this part of the river can only take place during the spawning-season, since salmon and trout only come there at that period, suitable fish are easily selected. Later, these fish are returned to their owners, who would lose all their privileges if they would refuse to submit to this arrangement. This excellent idea, somewhat modified, has been put into practice in two rivers of the canton of Vaud, the Thièle and the Arno, and the persons who rent the fisheries are obliged every year to deposit some fecundated eggs in the fish-ponds established near each of these rivers.

M. de Loës is subject to the same conditions as regards the canal running parallel to the Rhone, in which he is authorized to fish during the whole season. His hatching-establishment is well organized, and enables him to fill all the orders sent to him. After having procured all the fish he wants, he places them in his basins, waiting for the moment favorable for reproduction. The eggs are then placed on an apparatus, which receives water from an excellent spring in the mountains.

The hatching-process, which is always entirely successful, is conducted partly on sand and partly on clay.

The establishment for raising fish, located somewhat lower in the valley of the Rhone is fed from a very abundant spring, forming a brook, which M. de Loës has developed to the length of one kilometer, (⅝ of a mile,) by making it twist several times in a square, each side of which does not measure more than 100 meters, (328 feet.) Small lakes are arranged at certain intervals, and deep and well-shaded holes serve as a place of refuge to large numbers of fish of every age.

The results obtained by M. de Loës are very remarkable; and this learned pisciculturist has not yet said his last word in the matter.

From time to time piscicultural meetings are held in the canton, in order to make known all the secrets of this new science, which is destined to be of the greatest importance for Switzerland. We must confess we would like to see this practice introduced in France.

Numerous societies have been formed, especially at Fribourg, through the exertion of M. de Boccard, and in the neighborhood of Aigle, of which I will speak in another place.

3.—ITALY.

The necessity for replenishing rivers has not yet been felt in Italy as much as in other countries of Europe. This country, on account of its geographical position, offers exceptionally fine opportunities for fishing, and the seas which surround it on nearly all sides supply all the wants of its population. As in Switzerland, so there are also in Italy, many lakes containing various kinds of excellent fresh water, but Switzerland has no sea-fishing, possessing only its lakes, which would soon be exhausted if they were not constantly being replenished.

The rivers and brooks of Italy are, with few exceptions, dry during a great part of the year. Those water-courses which never dry up entirely experience such a large increase of water at the time when the snow melts, that it would be useless and even imprudent to found piscicultural establishments.

They do to-day what they have done for centuries. At Venice as at Naples, nothing is changed. At Commachio the same plan is followed as that which has been so well described by M. Coste. In the cities of the Adriatic and the Mediterranean, Ancona, Beri, Brindisi, Civita-Vecchia, Leghorn, Genoa, &c., the resources of the sea are inexhaustible. But it is none the less true that the persons who are at the head of the administration fully understand the necessity of revising the fishing laws, and a project for doing this will soon be laid before the Italian Parliament.

In Italy also the laws have become insufficient for protecting the fisheries; and waste, the use of hurtful fishing instruments, and the consequent destruction of fish, have made protective measures necessary. There is only one step from this to understand the necessity of replenishing those rivers which offer favorable conditions for so doing; and sooner or later the government will be obliged to interfere in the matter.

4.—AUSTRIA.

Artificial pisciculture has only been introduced into Austria during the last eight years. The imperial government has taken the initiatory steps by founding on its domains hatching-establishments from which every year many thousands of young fish are supplied to the lakes and neighboring rivers. The first establishment was that of Salzburg, founded in 1865. The government at first granted it a considerable annual subsidy, but for the last three years it has been able to cover its expenses, by raising from 10,000 to 15,000 young fish, and sending 3,000,000 of fecundated eggs to the different provinces of Austria, to Switzerland, Holland, and even to Hüningen.

At present every province of the empire possesses its own piscicultural establishment.

In upper Austria two societies have been formed, one at Linz in 1870, and the other at Ische in 1866; the former numbering 93 members, and the latter 29.

In the province of Salzburg the society has the name of "Central Institute of Artificial Pisciculture," and numbers 96 members.

In Tyrol a society was formed in 1869, consisting of 9 members; and another at Tarbole in 1873, numbering 42 members.

In Bohemia a society has been formed at Nachod, numbering 43 members.

In the province of Bukowina a society is being organized under the direction of M. L. Lindes, and the minister of agriculture has just granted him the sum of 800 florins.

We must here also mention the piscicultural establishments of the Princes Schwarzenberg, who have sent a number of specimens to the Vienna Exposition; the establishment of Baron Washington, the largest pisciculturist of Austria, at Wildon near Graz; and M. Pammer at Graz, who furnishes the river Murr with fish.

The Salzburg establishment, the largest of all, has been founded on the plan of the one at Hüningen. The hatching apparatus of the College of France is used in a somewhat improved shape. These apparatus hatch every year 3,500,000 eggs.

The establishment is located near the imperial castle at Salzburg, at the foot of the Alps, only two and a half miles from the city.

The basins to the number of fifteen are all fed by spring-water; they are partly covered so as to afford places of refuge for the young fish. The spring is in the house of watchmen and in the very place where the hatching takes place; a large basin of this fresh water surrounds the house, and in this those fish are kept which are destined for reproduction. The other basins, in which there are fish of every age, are comparatively small; that in which 20,000 young fish have been placed this year is only 2½ meters long, (nearly 4 feet,) 1 meter 20 centimeters broad, (about 3¾ feet,) and 35 centimeters (about 1½ feet) deep.

Two other basins are reserved, one for carp and the other for aquarium fish, which increase with an almost incredible rapidity, and being in proportion to the size of the establishment, whose area is about 30,000 square meters.

The food consists of white-fish and horse-flesh; and at the expense of about 2½ francs per day, 30,000 fish of all sizes are fed.

5.—MUNICH.

Bavaria has not remained behindhand, and pisciculture, which numbers many experts in that country, has made considerable progress. The fishing laws are very rigorous, but are very little regarded. The public markets are under strict superintendence, and considerable fines are imposed on those who repeatedly transgress the laws. The crawfish is numbered among that kind of fish whose capture is prohibited during the spawning season; females bearing eggs must again be thrown into the water, and none can be taken before they have reached their full size.

There are at Munich different establishments, that of M. Küffer affording great interest on account of the simplicity of its arrangement, the small space it occupies, and the great results obtained. I have there seen more than 200 trout, two years old, weighing on an average 350 to 450 grams (somewhat more or less than 1 pound troy) in a single stone vat 1½ meters long, (almost 5 feet,) 75 centimeters (2¼ feet) broad, and 60 centimeters (about 1¾ feet) deep.

In another compartment 2¼ meters (about 8 feet) long, 1½ meters (almost 5 feet) broad, there are more than 6,000 crawfish, the finest of which weigh 250 grams (3,750 grains) and more.

Salmon to the number of six, and weighing on an average 10 to 12 kilograms (about 25 to 30 pounds,) are packed so closely in one of these small vats, that it is impossible for them to turn round; yet they do not seem to suffer from this position, which they have occupied for a long time. These remarkable results have been obtained by constantly renewing the water, and by providing good and abundant food.

The experiments of M. Küffer have been specially directed to the acclimatization of the *Salmo hucho*, a variety of salmon which is peculiar to the waters of Bavaria, and which after the experiments made by the College of France could easily be acclimatized in France.

This fish, which to the characteristics of the salmon adds the stationary habits of the trout develops in a very short time; it can be acclimatized in every water, and does not suffer from a change of temperature; it is easily fed with white-fish and salt horse-flesh, after a new system which has stood the test of experience. M. Küffer carries on all his hatching-operations on sand.

In Bavaria I have made some observations which deserve attention. A number of species which serve as food, and which are very scarce in France and Switzerland, are very common in the lakes and rivers of Bavaria; carp, pike, and perch are almost given away in the Munich market.

The question is naturally asked, why have those Bavarians who occupy themselves so much with pisciculture not endeavored to destroy the pike and perch, which are the sharks of the fresh water? I have learned the following regarding this matter. The pike and perch live in rivers where there are no fish of the salmon kind, but only white-fish; and on the other hand, fish of the salmon kind, live in water which contains neither pike nor perch, but white-fish, on which they feed.

Unfortunately, this is not the case in France, where fish of prey are found in all the rivers, which to a great extent depopulates them. The necessity of a good law regulating the raising of these species is being more and more felt as an essential condition for successful pisciculture.

In France, we must confess, there has recently been a time when but little was done; this time has been filled, it is true, by the progress of some establishments founded in the Puy-de-Dôme, in the Pyrenees, in Creuse, in Savoy by M. Costa Bauregard, in the department of Haute-Vienne, &c., and by the interesting publications of De la Blanchère, Haxo, Millet, Jourdier, Wallon, Koltz, Carbonnier, Chabot, Maslieurat, the Viscount of Beaumont, Lamy, Chenu, Blanchard, and the various communications made to the Academy of Sciences, &c., besides the societies of oyster cultivators which have been formed, and whose services will be appreciated at no distant period.

Several general conferences have favored private enterprise by extending financial aid; this ought to be followed up, and new resources should be given to France.

The essential point, as M. Coste has shown, is to preserve by artificial fecundation that innumerable quantity of eggs which are lost before being hatched, or in an embryonic state. In order to carry on these experiments on a large scale and to furnish an abundant supply of this "manna" to serve as food for the human race, the government ought to found four large establishments in the four principal basins of France, into which the rivers of our country are divided, and which would develop pisciculture to its greatest possible degree.

A committee appointed by the government and composed of experts and engineers should examine the rivers, and in each basin designate the most favorable place.

These establishments would afford the advantage of replenishing the rivers of the country with those species of fish that could live there, and would endeavor to acclimatize those species which on account of the changes of temperature are not accustomed to live in our climate. These studies might be accompanied by experiments with apparatus and the different systems of raising fish, and all these different experiments should be under the control of the College of France. The programme should embrace the influence of the nature of the water on the development and acclimatization of different species, experiments which are impossible in laboratories, which are generally only supplied with water of one kind; the different systems of food should also be studied. The administration of bridges and roads would, on account of its admirable organization, be naturally destined to be at the head of this whole undertaking and superintend it.

The reason that France has not advanced so rapidly in pisciculture as one had the right to expect after the convincing experiments of M. Coste, is that great ignorance prevails regarding the means to be employed. Many well-meaning persons have made and are making experiments yielding only a partial result. This is very obvious; not knowing the well-known processes, they are obliged to try everything, to learn everything, and to do a great deal by guess-work; those who are not discouraged after experimenting for two years, do not always possess the means to meet the new expenses which would be required. If they could acquire the knowledge they are in want of in model-schools of pisciculture, such as these four great establishments mentioned above would be, in the same way as the agricultural farm-schools, they would be sure to succeed, and would not shrink from sacrifices for which they would most assuredly in the end reap their reward. These model-schools would doubtless be a great success and would greatly increase the resources of France.

6.—THE GREAT BASINS OF FRANCE.

The basin of the Seine, which measures 4,327,000 hectares, (10,817,500 acres,) on an area of 800 kilometers, (500 miles,) and which is watered by the Aube, the Marne, the Oise, the Yonne, the Eure, &c., offers a most favorable location for the first of these establishments, viz, the basin of Settons, located in Morvan, and proposed by M. Coste.

In the basin of the Loire, which comprises one-fourth of France, and whose principal tributaries, the Mayenne, the Sarthe, the Allier, the Cher, the Indre, and the Vienne, traverse more than 1,100 kilometers, (687 miles) it would be easy to place a second piscicultural establishment, either between Orléans and Tours, or near Clermont-Ferrand and the neighboring lakes, especially Lake Pavin, called the "Dead Sea" of Auvergne.

The third establishment should be placed in the basin of the Garonne, the Dordogne, and the Gironde, to which the secondary basins of the Charente and the Adour would belong.

As regards the basin of the Rhône, whose course in France is 520 kilometers, (325 miles,) the fourth establishment ought to be placed above the junction of the Rhône and the Saône.

The *féra*, (*Coregonus fera*,) found in large numbers in the Lake of Geneva, through which the Rhône flows, could be acclimatized in the waters of Bourget, or in the lakes near the Puy-de-Dôme. What a fine field for experiments could be opened to human industry in France, and what immense resources could be opened for supplying the people with food!

The following conclusion is easily reached: By the side of the laboratory of comparative embryogeny of the College of France, from which most of the physiological prizes come which are given by the Academy of Sciences, the Laboratory of Pisciculture is placed, which, up to the present time, has always given information and advice, and which popularizes the progress which science makes every year.

The four establishments which we desire to see founded would not cost more than the single establishment at Huningue, and would spread a knowledge of and a taste for pisciculture; it would be their duty to apply practically all the discoveries which have been made; they would spread life and abundance in the four great basins of France; they would greatly develop the river-fisheries, and would create the necessary regulations; they would replenish with fish the Seine, the Loire, the Garonne, the Rhône, and their tributaries; they would point out the species most suitable for each part of the country, and would open out vast resources of private industry by the founding of smaller establishments.

This is the object we aim at, with good chances for success, and which we will doubtless obtain if the government will aid us in our efforts.

D—THE PROGRESS OF FISH-CULTURE IN THE UNITED STATES.

By James W. Milner.

1.—THE METHODS EMPLOYED IN FISH-CULTURE.

There are three methods in use for the increase of fishes; the first two employed from a very early day, and the other of quite recent origin. As all of these methods have been applied in the United States we will consider them in order. The first is the transfer of living fishes from their natural haunts to new waters, or to a confined area in their own stream, lake, or arm of the sea, where they are either left to depend on such food as the water may afford, or else are supplied with it from elsewhere.

The second method is the gathering of eggs naturally impregnated and deposited, and placing them in ponds or streams, or caring for them during the period of incubation in suitably-arranged apparatus.

The third method, and the one by which the more important results have been attained, consists, primarily, in the artificial fecundation of the ova, (expressing the eggs and milt from ripe fishes together in a vessel;) and secondly, in caring for them in suitably-devised apparatus through the egg-stage, and as far along during the embryonic life of the fish as their welfare requires, when they may either be turned out to shift for themselves, or else kept in properly-arranged ponds or otherwise, and fed as occasion requires for an indefinite period of time.

It has been quite a usual habit in writing on the subject of fish culture to attribute the origin of the art to the Chinese, and many have been led to believe from the frequent assertions to that effect that the artificial fecundation of fish eggs was practiced by the Chinese, who thus anticipated the Europeans. The principal data relating to fish propagation in China are to be found in the publications of the *Société d'acclimatation* of France, and in a large work published in Paris in 1872 entitled "*La pisciculture et al pêche en Chine*," by P. Dabry de Thiersant, with an "*Introduction sur la pisciculture chez les divers peuples*," by Dr. J. L. Soubeiran. A "History of the Chinese Empire," by Father Duhalde, a Jesuit missionary, also contains a reference to pisciculture. Special inquiries have also been made by Mr. George Shepard Page, of New York, through the State Department, and satisfactorily answered.

All authorities agree with reference to the antiquity of the practice by the Chinese of the first two methods described, but no evidence is produced that they have now or ever had any knowledge of artificial fecundation of the eggs of fishes as employed by Europeans.

At the present day a certain class of the Chinese devote their time at the proper season of the year to the capture of quantities of embryo fishes, which are carried to ponds, streams, and lakes, and turned loose in their waters to increase their stock of fishes. These embryos are found in holes or pockets in the beds of the rivers, and are obtained by divers. Ova are also obtained in large quantities in the rivers, by straining the current through nets or mats, and intercepting the eggs as they are carried down stream.

2.—TRANSFER OF LIVING FISHES.

The pike or pickerel.—The transfer of fishes early gained the attention of the people in this country as well as in Europe, and it is a singular coincidence that in Central Europe as well as in different parts of the United States the same species, the lake pike, or pickerel, (*Esox lucius*,) received favor in this direction, both countries having afterwards had reason to regret its distribution. This fish, the merits of which are sometimes defended in regions where it is the principal species, is not only very destructive of other fishes, but is of indifferent flavor and full of bones.

In Maine, New Hampshire, and other States its introduction is now regarded as a mistaken enterprise, and the same expressions of regret that are found in the reports of the fish commissioners of some of the States, at its distribution in the waters, occur in papers on the fishery interests of Germany, and in certain English publications.

The disposition to introduce this species into new waters has been recognized, and its fatal error is so well understood that in some of the States laws have been enacted inflicting a fine upon any one convicted of having introduced the pickerel into waters where it does not exist.

The muskellunge.—About 1840 this species (*Esox nobilior*) was placed in a pond near Bellows Falls, Vermont, from which it escaped into the Connecticut River, and has maintained its presence ever since.

The black bass and Oswego bass.—The fish that before the days of artificial fecundation of fish eggs have been perhaps the most extensively introduced are the black basses of the species *Micropterus salmoides* and the *Micropterus nigricans;* the former being the one better adapted for clear streams and lakes, and the latter for grassy and comparatively shallow lakes and ponds. Mr. Thaddeus Norris relates in his volume on American angling that when a boy he knew of the stocking of a pond in the vicinity of Richmond, Va., with the black bass, (*Micropterus salmoides.*) Among numerous records of their introduction, in very few instances discriminating properly between the two species, we give the following: In 1850 twenty-seven live bass were brought by Mr. Samuel Tisdale, of East Wareham, Mass., from Saratoga Lake and put into Flax Lake, near his home. In the years 1851 and 1852, others were brought to the number of two hundred and reared in ponds in the vicinity. The matter was kept quiet and fishing discouraged for five years, when the fish were found to have increased very rapidly. Some twenty-five ponds were stocked in the same county after Mr. Tisdale had initiated the experiment. Afterward black bass from Mr. Tisdale's ponds were supplied to a lake in New Hampshire in 1867, and to waters in Connecticut and Massachusetts. In 1866 the Cuttyhunk Club, of Massachusetts, introduced the black bass into a pond in their grounds. In the year 1869 the commissioners of the State, together with private parties, stocked several ponds and the Concord River with black bass, and in the following year other waters were stocked.

In Connecticut, in the winter of 1852–'53, the black bass was introduced into Waramang Lake, in Litchfield County. They were brought from a small lake in Dutchess County, New York. A few years later they were said to have increased greatly. Another lake in the same county was stocked not long afterward.

Saltonstall Lake, near New Haven; East Hampton Pond, in Chatham; Winsted Pond, in Winchester, and many ponds and lakes of the State, particularly in the northwest portion, were stocked with the black bass previous to the year 1867.

In the years 1869, 1870, 1871, and 1872, thirty-seven lakes and ponds in different parts of the State were supplied with black bass.

As early as 1864 or 1865 black bass had been put into Rust's Pond, near Wolfborough, New Hampshire; in 1868 a few were brought to Charlestown and lakes Massabesic, Sunapee, Pennacook, and Echo, and Enfield, Wilson's, and Cocheco Ponds were well stocked; in 1870 and 1871 the New Hampshire commissioners introduced the black bass from Lake Champlain into the waters of the State at Meredith, Canaan, Webster, Canterbury, Harrisville, Munsonville, Hillsborough, Warner, Sutton, New London, Andover, Loudon, Concord, and in Croydon. In Massabesic and Sunapee Lakes, where they had been introduced, in 1868 and 1869, they were found to have increased, and, on the authority of Dr. W. W. Fletcher, they have become exceedingly numerous in Sunapee Lake.

The commissioners of the State of Rhode Island, since 1870, have stocked thirty ponds or small lakes in different parts of the State with the black bass.

In Maine, in the fall of 1869, the State commissioners and the Oquossoc Angling Association introduced from Newburgh, N. Y., a quantity of black bass. The waters of Duck Pond, at Falmouth; Fitz Pond, in Dedham; Newport and Phillips Ponds, Cochnewagan Pond in Monmouth; Cobbosseecontee Lake, in Winthrop and adjoining towns, were stocked, and a few years afterward were reported to have increased largely in numbers.

Since the year 1871 black bass (*Micropterus salmoides*) and Oswego bass (*Micropterus nigricans*) have been put into seventy lakes, ponds, or streams of the State of New York by the commissioners. They had made their way of their own accord through the canals connecting Lake Erie with the Hudson into that stream.

Private citizens of Pennsylvania introduced the black bass (*Micropterus salmoides*) into the Susquehanna about 1869, at Harrisburg. In 1873 the tributaries of the Susquehanna, the Potomac, and Delaware Rivers were supplied with black bass by the commissioners at thirty-five different points.

In the year 1854 Mr. William Shriver, of Wheeling, Va., planted in the canal basin at Cumberland, Va., his former home, a number of the black bass, (*Micropterus salmoides*;) from the basin they escaped into the Potomac River, where they have increased immensely at the present day. They were moved from the waters of the Ohio River to their new locality in the tank of a locomotive. Numerous cases have also occurred of transfer from one locality in the Southern States to another.

There have been very many transfers of these valuable species that have not been recorded, as they are easily kept alive while being moved from one place to another, and propagate surely and rapidly in ponds, lakes, and rivers.

These details are given because they show the facility with which comparatively barren waters may be stocked to a considerable extent with good food-fishes, and they exhibit the general interest and attention that have been given to this mode of propagation.

The wall-eyed or glass-eyed pike.—The wall-eyed pike (*Stizostedium americanum*) is another species that has received favor for this purpose. It is a fine-flavored fish, somewhat predatory in its habit, and not so generally adaptable to waters of all characters as the black bass. In the great lakes and rivers, where it finds a favorable home, it multiplies to a much greater extent than the latter species. It had been introduced in some of the lakes of New Hampshire, New York, and other States.

The eel.—The eel, (*Anguilla bostoniensis*,) appreciated in some localities and much vilified in others, is another species that has been frequently transplanted. It is pretty evident that it never existed naturally in the chain of great lakes any higher up than Niagara Falls, although specimens have been taken in Lakes Erie and Michigan. Their existence there is with little doubt traceable to artificial transportation.

A captain of a lake-vessel informed me that it was quite a common thing, some years ago, to carry a quantity of live eels in a tub on the deck of a vessel while on Lake Ontario, and they were often taken in this manner through the Welland Canal. He said that it was a frequent occurrence on his vessel when they had become tired of them, or had procured better fishes, to turn the remainder alive into the waters of Lake Erie.

In 1871 Mr. A. Booth, a large dealer of Chicago, had an eel of four pounds weight sent him from the south end of Lake Michigan, and a few weeks afterward a fisherman of Ahneepee, Wis., nearly two hundred miles to the northward, wrote him that he had taken a few eels at that point. It was a matter of interest to account for their presence, and a long time afterward we learned that some parties at Eaton Rapids, Mich., on a tributary of the lake, had imported a number of eels and put them in the stream at that place, from which they had doubtless made their way to the points where they were taken. The unfortunate aquarium-car in June, 1873, by means of the accident that occurred at Elkhorn River, released a number of eels into that stream, and about four thousand were placed by the United States commission in the Calumet River at South Chicago, Ill., two hundred in Dead River, Waukegan, Ill., and three thousand eight hundred in Fox River, Wisconsin.

The alewife.—The alewife (*Pomolobus pseudoharengus*) has in numerous instances been largely multiplied by carrying the parent-fish above the dams that prevented access to their favorite spawning-grounds, or even to new waters. According to General Lincoln, an experiment of this kind was made successfully as long ago as 1750. This has been a common practice in the shorter rivers on the Massachusetts coast, generally with good results.

The smelt.—The introduction of the smelt (*Osmerus. mordax*) into new streams and lakes has been attempted by New Hampshire and Massachusetts. In New Hampshire three lakes were stocked in 1871, and in Massachusetts it is said that Jamaica Pond was stocked near the close of the last century, and that they have existed there ever since, without access to the sea. In 1869 they were introduced by the commissioners into Flax Pond, in Wareham.

The white fish.—Mr. L. J. Farwell, of Madison, Wis., formerly governor of the State, transferred in 1854 a number of white fishes, (*Coregonus albus*,) together with the brook-trout, (*Salmo fontinalis*,) to the lakes around Madison. As the white-fish are only taken with nets their presence in the lake was only manifested when suitable nets were made use of. Elizabeth Lake, in Oakland County, Michigan, was stocked with this species many years ago, and it has since increased to a very large extent, and affords a considerable income to the owners of the property on the lake who control the fisheries.

The salmon or lake trout.—A considerable number of this species, (*Salmo namaycush*,) obtained in Lake Ontario was introduced into Newfound Lake, New Hampshire, in 1871, by the State commissioner. In 1866 a number of land-locked salmon, (*Salmo sebago*,) had been brought to this lake from the St. Croix River.

The brook-trout.—The brook-trout, (*Salmo fontinalis*,) the favorite of anglers, has, of course, received much attention in this direction.

There are numerous instances related of their being introduced into new waters from neighboring streams. Even in the interior of the country they have been transferred southward among the drift ridges and prairies from the more northern rocky streams of Michigan, Wisconsin, and Minnesota. Generally this has been done for the purpose of stocking breeding-establishments.

A stream at Lake Forest, in Northern Illinois, flowing from an artesian well, was supplied with live trout brought from Wisconsin, but none of them lived, probably because of the high temperature of the water. The distribution of this species from breeding-establishments has been very extensive.

3.—THE TRANSFER OF NATURALLY-DEPOSITED EGGS.

Spawning races.—Of the second method there has been comparatively little application in the United States.

The experiments in hatching black bass by placing the pairs in a box similar to the one used by Lund in 1760, and the methods employed for obtaining trout-spawn originated by Ainsworth and Collins, are of this character.

The simple apparatus employed by Mr. Ainsworth was merely an adjustable section in a narrow raceway constructed in such a situation as would induce the trout to enter from the deeper water for the purpose of digging their nests. A screen of coarse-wire cloth covered loosely with gravel constituted a false bottom to this box, through which the eggs, on emission, fell to the real bottom below.

The Collins apparatus was an improved modification of this principle, inasmuch as it obviated the necessity of disturbing any portion of the raceway, the eggs falling through the upper screen upon a revolving apron, or wide belt of wire cloth beneath, when, by turning the drums on which it rolled, the eggs were carried to one end, and fell over into pans placed to catch them.

The greater percentage of fertile eggs from artificial impregnation has induced, in later years, very little use of these methods, except where it is regarded as desirable to avoid the cold and often severe exposure to the person impregnating eggs in cold weather.

Hatching from the offal of dead fishes.—There exists quite a prevalent notion that the stock of fishes may be protected from diminution to a considerable extent by returning the offal from fishes dressed for salting, containing the ovaries and spermaries, to the waters from whence the fishes are taken. This is done to a large extent at Sandusky, Ohio, on Lake Erie, where the white-fish (*Coregonus albus*) is taken in large numbers in the spawning-season, and the fishing-grounds are so far off from the curing-houses that but little damage is done by the presence of the decaying matter.

That the ova from fishes dead for a short period of time may be fertilized and hatched has been proven by experiment by embryologists and fish-culturists.

Jacobi, in his early experiments, found that young fishes could be developed from the eggs and milt of fishes recently dead.

M. de Quatrefages, in referring to the fertilization of fishes, says the fecundation should follow soon upon the death of the male fish, and the second clause of his directions says, "Since the fecundation should take place within a day or twelve hours after the death of the fish, the spawn should then be taken."

In Carl Vogt's essay on artificial fish-breeding he says, in speaking of the fertilizing power of the spermatozoa: "At low temperatures this power is retained for hours and even days if the milt remains in the organs by which it is secreted. In the Lake of Neufchatel (Switzerland) the paleé, (*Coregonus palea*,) a fish of the trout family, is taken, during the winter months, by night or at sunset. I have often received these fish stiff-frozen, and succeeded perfectly in impregnating spawn with the milt taken from the genitals of the male the day after."

On page 497 of this report is a reference to the success the Russian fish-culturists have had in hatching the eggs from dead females impregnated with the milt from dead males, the claim being made that the milt retains its vitality for a long time if left within the reproductive organs.

Mr. Atkins (see pp. 285–'86) gives the percentage of eggs fecundated taken from dead females, as follows: From a salmon that had been dead two hours, at .58½; of eggs from two dead females, at .67½; of eggs from two dead females, at .35; of eggs from dead fish, .92½; of eggs from dead fish, .30; of eggs taken from dead fish the day before, .12½; of eggs taken on November 11 from specimens killed on the 9th, .0; from a fish that had been dead fifteen hours, .0. The experiments with eggs from live females, to which the milt from dead males was applied, gave the following results: Female ripe and good, milt, about a teaspoonful, from a dead fish taken before the eggs, .2½; eggs kept in a pan without water thirty hours, milt from a male that had been dead two days, .0; from eggs kept the same length of time, treated with fresh milt, .87½; eggs kept without water four days, milted with milt from dead fish, .0; eggs kept four days without water, then milted with new milt, .12½.

The indications from these few experiments are that the eggs retain their vital powers much longer than the milt within the dead bodies of the fish.

The experience of fish culturists is certainly in favor of the immediate use of the milt from the living male fish, their experiments indicating that the vitality of the milt continues for but a few minutes when diluted with water, and even undiluted its certainty of effect rapidly decreases to zero.

That eggs and milt retain sufficient vitality when removed from fishes but a short time dead to produce a living embryo may be true, but there is also quite a possibility that there would be less vigor in the embryos and in the growing fish than in the case of eggs and milt from a live fish.

One of the investigators of the incipient embryonic development, studying the process in the amphibia,* as one of his conclusions, makes the following statement: "Partial impregnation is shown in imperfect segmentation of the yelk, and is due to the spermatozoa being insufficient in quantity, or in duration of contact, or inefficient through diminished vitality; and it may also result from diminished susceptibility in the ovum." It will readily be admitted that some of these unfavorable conditions are very liable to occur when the spermatozoa or ova from dead fishes are used.

The small per cent. of fishes produced from a quantity of eggs where there is the slightest lapse of care and attention on the part of the breeder is convincing evidence to all who have had even a slight experience that no large results could be expected from this practice. Where the fishes are taken near the curing-houses and are dressed within a short time after death, in all probability a small portion of the ripe eggs would develop into fishes; but in localties where many of the fisheries are situated, the fishing-grounds are so far away that the fish are dead for several hours before they reach the shore, and the percentage of fishes produced from the spawn would be very small, if anything.

4.—ARTIFICIAL FECUNDATION.

Introductory remarks.—The evidences advanced to prove a knowledge of the third method referred to, before the time of Jacobi, are not, so far, sufficiently definite, and the data produced by Baron de Montgaudry to show that Dom Pinchon was the inventor of the art, in so far as it involves artificial fecundation, are very unsatisfactory.†

The description he gives of the apparatus proves Dom Pinchon's process in caring for the eggs during the period of development to have been the

* On the Impregnation of the Ovum in the Amphibia, and the direct agency of the spermatozoon; Proc. Roy. Soc. June 17, 1852, George Newport, F. R. S., &c.

† Bulletin de la Société Zoologique d'Acclimatation. Fondée le 10 Février, 1854. Tome premier. Paris, 1854, p. 80.

original of the trough method. The manner of procuring of the eggs is not referred to; he merely explains how he prepared the bed of sand upon which to deposit the eggs which he had previously made fecund.*

The baron based his statements upon the manuscript found at Reome, without quoting from it, and leaves his readers in ignorance as to whether the mode of obtaining the eggs is described in the original.

In the absence of any publication of the manuscript the only data to support the claim are the statements made by Baron Montgaudry and the reference in a foot-note of Jules Haimé's paper on pisciculture (see page 472) to the method employed for obtaining the eggs; this information on the subject afforded by Baron Montgaudry, and referred to in the foot-notes, was probably imparted in conversation, as there is no record of it in the papers published in the Bulletin or in the report of the *Procès-verbaux des séances* of the society from the time of Montgaudry's references to Dom Pluchon to the date of publication of Jules Haimé's paper.

The publication of the manuscript, if it is still in existence, would clear up the uncertainty and afford a definite record for the history of this important advance in the art of fish culture.

To J. L. Jacobi, lieutenant of Lippe-Detmold, a German principality, belongs the credit of discovering and making public in a journal published in Hanover in 1763, the methods in the art of fish culture now used in modified and improved form.

The description of his box accords in general form and proportions with the trough in modern use. It was 12 feet long, 6 inches deep, and 18 inches wide. It lacked the cleat partitions now used that divide the troughs into nests, the eggs being sheltered from the force of the current by hollows and cavities in the bed of gravel in which they collected. The water supplied to the trough flowed through a screen or grate of brass wire, and the outlet was guarded by a similar screen. The screens would be considered of rather large mesh for use in the hatching establishments of the present, as they were about eight wires to the inch. Jacobi regarded covers to the troughs as a necessity, but not for the purpose they are now deemed essential. There is no evidence from his letter that any building or roof was thought of in connection with his troughs, and tight covers were necessary to protect the ova from their natural enemies, the one he most dreaded being the water shrew; this use of a screen under the supply-stream being more with regard to protection from this animal than for the purifying of the water.

Spring-water from a rocky, pebbly locality he considers to be the best. The supply of water to each trough, he asserts, should be an outflow of a pipe one inch square, with one or two feet head, and should

*Il préparait une légère profondeur dans la couche de sable pour déposer les œufs, qu'il avait préalablement fait féconder.

cover the gravel one or two inches deep. In the use of several troughs he provides for a main pipe, conducted across the head of the troughs, with outflows into each. "This done, you have all the apparatus necessary for breeding trout and salmon."

Jacobi understood that only a small quantity of the milt was necessary, because it contained vast numbers of the spermatozoa, and would fertilize a large number of eggs.

His manipulation of the male and female trout, stirring the milt through the eggs, and the addition of fresh water after impregnation of the eggs, is very similar to modern practice. The necessity of separating the eggs in the troughs was well understood, though, instead of a feather, he, by means of a thin paddle of wood, produced an eddy in the water that spread the eggs over a larger surface. The fine, downy fringe of the conferva growth was a difficulty he had to contend with as well as modern workers in the art, and the little trout of ancient times had the same tendency to hide themselves in the gravel when young that they do at this day.

His gratings did not prevent the egress of the young fishes, and he provided them with nurseries at the end of the troughs. Monstrosities, in the shape of double-headers, he seems to have been familiar with, and found them short-lived.

Jacobi seems to have been a man of intelligence and application. Some of his conclusions, however, have since been entirely disproven by investigators in embryology.

The progress made in the methods and apparatus of fish culture has been very great, as the result of the experience of many experts, and in certain lines is entirely new and novel; but the present graveled trough method for hatching trout and salmon is only an improved modification of the boxes and troughs used by Dom Pinchon and Jacobi.

The necessity of filtering the water through screens, the advantage afforded by dividing the troughs into nests, by means of cleats, so that the bed of gravel may be kept level, and prevent the tendency of the eggs to collect in heaps, the shutting out of light from the eggs, the immense reduction of loss from the removal of dead eggs and fungus growth, the transportation of partly-developed eggs, and feeding young fish with prepared food, were all entirely unknown to the earlier authors; as also the numerous improvements in the manipulations, the guarding against the ills incident to the eggs and young fishes, that have grown up in the experiences of the numerous workers in the art. Jacobi, indeed, does not seem to have carried forward his discovery to any extensive practical result, although an establishment at Nortelem was sustained for a short time, and the English government had sufficient appreciation of his work to afford him a pension.

Adanson, in a course of lectures delivered in Paris in 1772, made the statement to his auditors that the art of fish culture was prosecuted with success on the river Weser, in the Palatinate of the Rhine, and in some of the higher mountainous portions of Germany.

The Abbe Spallanzani, an Italian, in 1768, employed artificial fecundation in his studies of the embryology of the frog, and Monro Rusconi, also an Italian, in 1824, artificially fecundated and hatched the eggs of a cyprinoid fish, the tench (*Tinca vulgaris*) while prosecuting investigations in embryology.

In 1837 John Shaw practiced the art with the salmon in the river Nith of Scotland, and made use of his experience to extend the knowledge relating to the growth and development of the young salmon.

Joseph Rémy, a fisherman of the department of the Vosges, France, discovered and applied, about 1842,* the methods of artificial fecundation on the trout. Afterward uniting with him Antoine Gehin, they continued the work with ample success in the rivers of their region. It was from the work of Rémy and Gehin that the great impetus and extended efforts in fish-culture had an origin, when it had been brought to the notice of the world by the French scientists.

The artificial propagation of fishes is now extensively practiced in Great Britain, France, Belgium, Holland, Denmark, Norway, Sweden, Russia, Germany, Hungary, Switzerland, Italy, and Spain, in Canada and in our own country, while India, Java, Australia, and Tasmania have instituted investigations by fishery commissioners and have imported valuable species of food-fishes.

In the United States the first published record of an experiment in artificial fecundation was made by the late Rev. John Bachman, D. D., the naturalist, of Charleston, S. C., who was associated with Audubon in his work on the quadrupeds of North America.†

In 1855 he read a paper before the State Agricultural Society, at Columbia, S. C., describing his successes when a boy, in the year 1804, in impregnating and hatching the ova of the *corporal*, probably the *Semotilus corporalis*, (known in Pennsylvania as the fall fish,) and of the trout, (*Salmo fontinalis.*) In his paper he states that the eggs of both species were artificially fecundated and hatched, and that the trout attained some growth while confined in the ponds he had constructed.

The trout was the fish selected in the United States from the first as the favorite for artificial culture. In 1853 Theodatus Garlick, M. D., and Prof. H. A. Ackley, of Cleveland, Ohio, incited by their knowledge of the interesting results of the fish-culturists in France, began an experiment with the brook-trout, (*Salmo fontinalis*,) in which they were quite successful. In 1857 Dr. Garlick published a treatise on artificial propagation of fishes, appearing first in a series of numbers of the Ohio Farmer, and afterward gathered into a volume.‡

* See the foot-note referring to the claim of Gottlieb Boccius, to have preceded Rémy in the practice of artificial fecundation, on page 477.

† The Viviparous Quadrupeds of North America, by John James Audubon, F. R. S., and the Rev. John Bachman, D. D. New York: Published by J. J. Audubon, 1846, 4to.

‡ See title at foot of page 536.

To these gentlemen should be ascribed the merit of inaugurating the interest in fish-culture in this country.

Mr. E. C. Kellogg, of Hartford, Conn., and Mr. D. W. Chapman, of New York, began breeding operations at Simsbury, Conn., as early as 1855, and published their results before the Connecticut State Agricultural Society in 1856. A number of trout were captured and confined, the eggs fecundated and placed in boxes with gravel on the bottoms, through which a stream of water was led. At this first attempt seventy-five trout were hatched; some of them were taken from the pond the next season. In 1856 Mr. Kellogg's efforts were not very encouraging, because, as he believed, the eggs were not sufficiently mature, and arrangements for hatching in the cellar of his house at Hartford were imperfect. In 1857, with the apparatus in his cellar, and using water from the regular city supply, he hatched four hundred trout. In 1859 Colonel Colt, of revolver fame, made very complete arrangements for trout-hatching, of which Mr. Kellogg took charge, and about four thousand eggs were impregnated and placed in the hatching establishment

In 1857 the State of Connecticut passed an act affording certain powers and control of Saltonstall Lake for the purpose of fish-breeding, and increase in the interest of Mr. Carl Muller, of New York, and Mr. Henry Brown, of New Haven. They also obtained certain riparian privileges from the owners of property bordering on the lake. A stream tributary to the lake was selected as the breeding locality.

In May of the same year they are said * to have artificially fecundated twenty millions of eggs of the wall-eyed pike, (*Lucioperca americana*,) and to have transported them from Lake Ontario to the lake, where they were placed in the bed of the stream referred to and on the lake bottom, but the young fishes were all supposed to have been destroyed by a sudden freshet.

In November of the same year they visited Lake Ontario, and taking males and females of the salmon trout, (*Salmo namaycush*,) and the white fish, (*Coregonus albus*,) alive from the nets of the fishermen, they impregnated a large number of eggs, estimated by them at five millions for the trout, and one million for the white fish. They were packed in alternate layers with fine, wet sand.† The eggs were said to have the appearance of being in good condition when they arrived and were deposited, the white fish ova upon the sandy spots and the trout ova upon gravelly places in the stream-bed. In the March and April following the young were said to have been seen in large numbers.

In the autumn of 1858 ten millions ova of trout and white fish were again obtained and placed in the lake and stream, and considerable numbers were believed to have been hatched. Trout are said to have been taken afterward partly grown.

* Report of the Commissioner of Patents for the year 1859. Agriculture, Washington, 1860. Article fish-breeding, by J. C. Comstock, of Hartford, Conn., p. 227.

† Probably largely overestimated in both cases.

In 1859 Mr. Stephen H. Ainsworth, of West Bloomfield, N. Y., began operations with the brook-trout in a small stream and with good success. His successes and his generous spirit toward all who visited him, or sought information by letter, have largely influenced the spread of the interest throughout the country.

Seth Green's establishment, at Caledonia Springs, near Rochester, erected in 1864, was the first hatching-house in this country large enough to prove the importance of fish-culture as a pecuniary investment. It took but a short time to establish the fact, and from the interest excited, by his very marked successes, among the newspapers and magazines, the art obtained its great impetus in this country.

The brook-trout.—As stated, attention was at first, and it is equally true that it remained for a long time, concentrated almost entirely upon the brook-trout, (*Salmo fontinalis.*) This fish is a general favorite, because it combines all the desirable qualities demanded by sportsmen, epicures, and others. It has beauty of color, form, and movement; is adapted to scientific fly-fishing, being sufficiently shy to be tempted only by skillful and experienced anglers, and, when hooked, fighting long and pluckily against the attempt to lift it from the water, and, withal, superior in flavor, moderately prolific, and adapted to small streams and ponds if sufficiently cool, so that owners of such waters may have it as a possession almost as much under their control as their cattle or horses.

This general demand for the living fish has made it much more profitable than if merely propagated as an article of food, as the sale of ova and young fishes bring better prices with smaller outlay than where the fish are retained and fed and cared for until they are mature.

That it is possible to raise them profitably merely as an article of food has, however, been established in one or two instances where the facilities for breeding large numbers and procuring their proper food in abundance and cheaply have been afforded.

The breeding of trout among the different and widely separated culturists does not seem to have developed lately any marked or novel improvements in apparatus, though valuable modifications of methods have been attained.

The graveled troughs are in most general use, though a few prefer the apparatus invented by M. Coste, professor of embryology in the College of France, the Coste hatching-trays, with glass grilles or parallel rods, upon which the eggs are placed.

As already stated the advances in the art of fish-culture in general both in America and in Europe, have been largely the result of efforts at multiplying the brook-trout of the two countries respectively. Whether we consider Bachman or Garlick as first to initiate the work in the new world, it was with the trout that the labors of both were connected. A comparison of the claims of these pioneers may result in giving Doctor Bachman the priority in time, but his labors have had little or no influence in developing interest in or adding to the knowledge of the art. In fact, the doctor, who is remembered by his friends and acquaintances as a man of amiable qualities and modesty of disposition, makes no claim to having published any account of the matter prior to 1855, two years after Doctors Garlick and Ackley had begun their work.

An account was first given by Doctor Garlick, in the Ohio Farmer, of the methods of trout-breeding employed by himself and Doctor Ackley within two or three years after beginning their experiments; and in 1857 these papers were reproduced as a manual,* which has had a wide circulation. Their experiments with the trout, as also those of S. H. Ainsworth in 1859, were of the utmost importance in initiating the interest in pisciculture in the United States.

Seth Green began the famous establishment near Rochester, N. Y., in 1864, and from the first exhibited especial capacity and genius for the art. More than those of any other person in the United States, his labors have popularized the subject and extended the new industry throughout America, at the same time greatly improving and perfecting methods of work. In 1870, he published in connection with Mr. A. S. Collins, a manual of trout-culture,† which is still in demand.

In 1867, Dr. J. H. Slack purchased the establishment at Bloomsbury, N. J., founded by Thaddeus Norris, author of a work on fish-culture,‡ and who as far back as 1865, in his book on angling,§ devotes a chapter to fish-breeding.

Doctor Slack built up a successful establishment in a few years, and in 1872 published a manual ‖ on trout-culture, which contained the most correct history of the prosecution of the art in the United States that had been written, and a list of the works in the French and English languages, relating directly to practical fish-culture. His knowledge of

* A Treatise on the Artificial Propagation of Certain Kinds of Fish, with the description and habits of such kinds as are the most suitable for pisciculture, by Theodatus Garlick, M. D., vice-president of the Cleveland Academy of Natural Science, giving the author's first experiments contained in a paper read before the Cleveland Academy of Natural Science; also directions for the most successful modes of angling for such kinds of fish as are herein described. Cleveland, Thomas Brown, publisher, 1857.

† Trout-Culture, by Seth Green, published by Seth Green and A. S. Collins, Caledonia, N. Y. Rochester, N. Y., 1870.

‡ American Fish Culture, embracing all the details of artificial breeding and rearing of trout, the culture of salmon, shad, and other fishes, with illustrations. New York; 12 mo., 1869.

§ The American Angler's Book, embracing the natural history of sporting fish and the art of taking them, with instructions in fly-fishing, fly-making, and rod-making; and directions for fish-breeding, to which is added Dies Piscatoriæ, describing noted fishing-places and the pleasure of solitary fly-fishing. New edition, with a supplement, containing descriptions of salmon rivers, inland trout fishing, &c., &c. By Thaddeus Norris. Illustrated with eighty engravings on wood. Philadelphia, E. H. Butler & Co.; London, Sampson, Low, Son & Co., 1865.

‖ Practical Trout-Culture, by J. H. Slack, M. D., commissioner of fisheries of New Jersey; natural history editor of "Turf, Field, and Farm," New York; proprietor of Troutdale Pond, near Bloomsbury, N. J. "We speak that we do know and testify hat we have seen." New York: George E. Woodward; Orange Judd & Co., 245 Broadway, 1872.

French enabled him to gather in the valuable points in the experience of French culturists, which, in the true scientific spirit, he imparted to the public.

Doctor Slack invented a vessel for the transportation of fishes, which he called the "Troutdale transit-tank." This is a can of galvanized sheet-iron, holding ordinarily about twelve gallons, having a pan with a perforated bottom fitting into the top, to contain ice for the purpose of reducing the temperature of the water. In the top of the pan is inserted a high cover, having windows of perforated tin, surrounded by a belt or cylinder of the sheet-metal, arranged with openings corresponding to the windows, so that drawing the belt for a short distance around the top closes them. On the outside an air force-pump is attached, with a hose leading through the bottom of the tank to a rose that divides the air into fine particles before it ascends through the water, thereby aerating it in a most effective manner. This is a most invaluable arrangement where fresh supplies of water are difficult to obtain. This apparatus is described in his manual with an illustration, and its use tendered to the public, no patent having been secured upon it.

In 1866 Mr. Livingston Stone began the work of trout-culture at Charlestown, N. H., making his efforts successful after a short experience, and in 1872 he published a manual* on the culture of the trout, embodying the most detailed directions and the most complete compendium of the methods resulting from experience in trout-culture that has thus far appeared.

The results of Mr. Stone's experience have been made very valuable in his book, not so much by the devising of new methods and apparatus as by the scientific manner of his study of the questions and difficulties that present themselves to all culturists. His accounts of the ills and diseases that prevail with trout and eggs, whether the remedies advocated are in all cases efficacious or not, are of great importance as describing their causes and defining their symptoms and consequences, the first step to a discovery of remedies. The knowledge of their character, of course, affords in a great degree precision in experiment and effort for their remedy and prevention. The tonic effect of fresh earth placed in the troughs under certain circumstances is probably of efficient value and has been indorsed by other culturists.

The supposed discovery of parasitic animals in the confervoid growth on injured fishes was probably the observation of certain reproductive stages of the *Achlya prolifera*.

Mr. N. W. Clark, of Clarkston, Mich., began a trout-establishment in 1867, and continued it a few years with success, until his time and

*Domesticated Trout: how to breed and grow them, by Livingston Stone, A. M., deputy United States fish-commissioner, proprietor of Cold Spring Trout-Ponds, secretary of American Fish-Culturists' Association, and editor of fish-culturists' department in "New York Citizen." "Purpurisque salare stellatus tergora guttis."—Ausonius, Idyl Tenth. "Make assurance doubly sure."—Macbeth, Act IV, Scene 1. Boston, James R. Osgood & Co., 1872.

attention became entirely engrossed in the propagation of other fishes. By his active interest in the art of fish-culture, and continual contributions to the press of Michigan, as well as a widely-circulated pamphlet* on the subject, he created a wide-spread interest in Michigan that has been largely influential in bringing about the judicious and efficient action on the part of the State government for the multiplication of food-fishes.

In treating of the progress in trout-culture, only those culturists are here referred to who have made their experiences and discoveries available to all by publication, and only those publications have been mentioned that were written by those pratically engaged in the work of trout-culture, and whose writings and teachings were derived from original experience.

The summary of advances made by the application of the art of fish-culture to the brook-trout in the United States may be repeated as follows: (1.) The establishment and development of interest in the work. (2.) A practical knowledge of the methods employed in the art. (3.) Diagnosis of the diseases and ills incident to the artificial propagation of fishes and the suggestion as to prevention and remedies for some of them.

The salmon.—Previous to the autumn of 1866 the efforts in fish-culture in America had been entirely in the direction of extending a luxury, as the brook-trout is properly considered in this light, its qualities, as before enumerated, adapting it rather to the appreciation and enjoyment of the fortunate few, than constituting an extensive food resource for the good of a large population. In this year, however, the attention of the Canadian provinces and the New England States became concentrated upon the salmon (*Salmo salar*) as there were the most apparent evidences of its decrease and of its probable extermination at no distant time in the streams where it formerly abounded.

At the period mentioned the propagation of the salmon was commenced in Canada on a thorough basis, a small building erected, and arrangements made for hatching out the eggs. Mr. Samuel Wilmot, of Newcastle, Canada, on Lake Ontario, undertook the direction of the work. He obtained fifteen mature salmon, but was deprived of eleven of them by the act of a band of marauders who feared that his presence on the stream would prevent their killing the salmon, contrary to the laws reserving and protecting them in the stream for spawning purposes. He was able to obtain and impregnate about 15,000 ova, of which a large proportion was hatched the following spring.

The next year a somewhat larger number was obtained and hatched, with moderate success, and some of the smolts from the preceding year found.

* Pisciculture, or Fish-Farming: an address before the legislature of Michigan on the artificial propagation of fish and the restocking of public waters of the State, delivered at Lansing, February 28, 1871, by Hon. N. W. Clark, of Clarkston, Mich. Detroit, 1871.

In 1868 a hatching-house of larger dimensions was built, and the experiment of using stream or surface water attempted, the hatching-establishments of America, with scarcely an exception, using water directly from springs. Mr. Wilmot's experiences have proved the entire success of stream-waters. He has continued to hatch large numbers of salmon from year to year, and has succeeded in amply stocking the streams of his vicinity.

He is quite confirmed in the belief that the salmon of the tributaries of Lake Ontario never go to the sea to spawn, but make the depths of Lake Ontario their home when they are not in the spawning streams.

For a few years he sold quantities of spawn to commissioners of fisheries and private citizens of several States; but the successes of this industry within our borders soon stopped the demand for imported ova.

In the year 1871 Mr. Wilmot made the experiment of planting a few thousands of young salmon in the waters of Lake Simcoe, tributary to Georgian Bay and Lake Huron, believing they would adapt themselves to these bodies of fresh water. During the same year he imported a number of the charr (*Salmo umbla*) from the breeding establishment at Keswick, England, receiving fifty of them in good condition, and placed them in the waters of his vicinity.

In the fall of 1866, when the salmon operations were begun in Canada, the commissioners of fisheries of the State of New Hampshire* made the initiative movement for the restoration of salmon by sending Dr. W. W. Fletcher, of Concord, to the Miramichi River, New Brunswick, to obtain salmon ova for the benefit of the Merrimack River.

He returned with about 20,000 eggs, a few of which were hatched in a spring near Concord, and the remainder placed in artificially-prepared beds in the bed of the river, where their development could be observed, and it was estimated that 90 per cent. of them hatched. In the following season the parrs were frequently seen.

The attempts at procuring eggs in New Brunswick were continued by Dr. Fletcher in 1867, and by Mr. Livingston Stone, of Charlestown, N. H., in 1868. The latter gentleman was sent under the patronage of the States of New Hampshire and Massachusetts, and established a hatching-house on the Miramichi in company with Mr. Joseph Goodfellow, of Newcastle, N. B., and under a permit from the Canadian department of marine and fisheries, on condition that half of the young fry produced should be returned to the streams of New Brunswick.

Through delay in receiving the official sanction of the government they were prevented by the local authorities from taking salmon, it being the close season on the river. This, however, came in time for obtaining nearly a half million of eggs, about one-half of which were transported to the United States, and distributed to hatching-houses in New Hampshire, Massachusetts, Connecticut, and New York.

From 1869 until 1872 salmon ova were purchased by the New England States from New Brunswick culturists, and from Mr. Wilmot, and in 1871

* For a full history of salmon culture in the United States, see page 226.

the attempt at obtaining eggs from salmon within the boundaries of the United States was begun* by Mr. Atkins, of Bucksport, Me.

The method adopted by him for procuring seed-fishes is by far the most efficient and certain of large results of any in use. The salmon, during the whole season prior to spawning, are obtained from the nets of the fishermen by purchase, and are moved by means of wells or live-boxes to the ponds prepared for their reception, where they are retained until the ova are ripe. By taking advantage of their instinct for seeking suitable spawning places they are at this time enticed into raceways, where they are easily taken by the operators, and the spawn and milt expressed, when they are returned alive to the ponds. Several experiments were made to discover what character of water was required to preserve salmon in good, healthy condition while confined in the ponds. The conditions of temperature below a maximum of 73°, or the depth above a minimum of four feet, did not seem to affect them as much as the penetration of light into the body of water, as the experiments made in water darkened from the coloring properties of vegetation through which it ran were more successful than in very clear water, even where the depth was slightly increased and the temperature much lower.

During his first year's experiments Mr. Atkins employed the dry method of fecundation, which had been brought to the notice of American fish-culturists by the translation from the *Bulletin de la Société d'Acclimatation*, August, 1871, of the observations of Vladimir Pavlovitche Vrasski in 1856. By reference to the essay on fish culture, by Carl Vogt, the embryologist, of Geneva, Switzerland, of which an abridged translation was published by George P. Marsh in 1857,† it will be seen that Vrasski was anticipated by him in the announcement at least, if not the discovery of this method.‡

In describing the process of artificial impregnation, Vogt says: "The eggs and milt should be received in a shallow vessel containing barely

* See page 233.

† Report on the Artificial Propagation of Fish, by George P. Marsh, Burlington, Vt., 1857.

‡ The studies of the embryologists from the time of Von Baer discovered the fact that the spermatozoa of many animals retained the power of movement for a long time while subjected to a microscopic examination. In fact, Von Baer believed them to have a separate, independent life from the animal to which they belonged. This view was confirmed by others, and it was carried so far as to regard them as possibly infusoria, and as in their habit entozoic or parasitic, within the organs of animals. The fact of their independent life was first disputed by Treviranus, who believed their movement to possess no voluntary character, and that in their structure and properties they were analogous to fibrils and particles in the pollen of plants. The later physiologists are inclined to accept the latter view, so that their possession of life is as a part of the animal from which they are thrown off. They have a capacity for sustaining vitality for a time after separation, somewhat as the blood-corpuscles do in the operation of transfusion, or as in epithelial cells. They thus become the medium for the transmission of a portion of the life of the male to the egg of the female, which previously is inert.

water enough to cover the eggs expected to be obtained, and a little experience will enable the operator to estimate the quantity accurately enough. An excess of water is injurious because it dilutes the milt, disperses the seminal animalcules, and diminishes the chances of impregnation." On another page he says: "Since, then, the egg completes its absorption rapidly, and the currents attracted by it very soon cease, and since the seminal animalcules speedily lose their vitality in water, it is a matter of great practical importance to perform the processes for facilitating impregnation with as little loss of time as possible. The best method is doubtless to mix the milt with water and then immediately drop the spawn into the mixture, as the attraction arising from the absorption of water by the egg serves to direct and facilicate the movement of the animalcule toward the orifice, and this conclusion is abundantly established by observation."

It has been stated that Seth Green early applied these principles in fecundating eggs, and it is regarded as largely the secret of his success. If so, however, he kept his method a profound secret, not exercising it in public, or making any reference to it in his work.

In 1872 Mr. Wilmot, in his report* to the Department, asserts that experience taught him each year to use less and less water, and, finally by experiment, that his greatest results were attained without water, and in 1872 he adopted the system of dry impregnation.

The American system of dry impregnation, which from present record would seem to have been originated by Mr. Atkins† in 1871, differed from that of Vogt and of Vrasski, inasmuch as he did not dilute the milt or allow water to come in contact with eggs or milt until a full application of pure milt had been made. The contact was secured by moving the eggs rapidly in a pan, the milt and eggs being thus thoroughly mixed, after which water was poured into the mixture.

In the fall of 1872 Mr. H. F. Dousman, of Waterville, Wis., extensively engaged in trout-culture, applied the dry method of fecundation and frequently with this modification, that, instead of obtaining contact of eggs and milt by stirring them together, he trusted entirely to the persistent impulses of the spermatozoa to move directly forward, and covering the bottom of a pan with ripe trout-eggs, applied the milt in several spots, when, after a few minutes, it could be detected by its milky appearance to have diffused itself among all the eggs.

Mr. Livingston Stone, in his operations in California in 1872, while procuring spawn of the Sacramento salmon, (*Salmo quinnat*,) continued putting eggs into the impregnating pans until they were half filled before he applied the milt, and then stirred them with his hand until thoroughly mixed before he poured in water. He succeeded by this method in impregnating nearly 100 per centum of the eggs.‡

* Annual Report of the Department of Marine and Fisheries (Canada) for the year ending 30th June, 1872. Appendices of the Fisheries Branch of Department Marine and Fisheries, p. 96.

† See page 239. ‡ See page 173.

The experience of all indicates that the continuation of vital functions after removal from the living fishes or while retained in the body after death, is retained much longer by the eggs than by the milt. When in Mr. Atkins's experiments they were taken at the same time, it was found that the eggs could be fertilized with fresh milt long after the stale milt had lost all power. The series of experiments in different methods of fecundation by Mr. Charles G. Atkins* prove the dry method to be much superior in its results to the use of water at the time of expressing eggs and milt. This seems to be the uniform testimony of all who have tested it.

The apparatus used by Mr. Atkins, in 1871, was the ordinary trough, but instead of covering the bottom with gravel, upon which to place the eggs, he arranged strips of glass transversely in frames, which were set all along the length of the trough, and about an inch above the bottom. Upon these the eggs were placed, arranging themselves in parallel rows, and having a free circulation of water on all sides.

In 1872 a large building was erected,† troughs put in, and wire-cloth screens or trays, on light wooden frames arranged about five-eighths of an inch from the bottom, were fitted to the troughs. These devices were improvements, though not the first in use,‡ upon the ordinary graveled troughs.

The breeding establishments in different parts of the country received the salmon-eggs from places where they were procured and partially developed, and in this way they were distributed over a considerable extent of country, the most extensive distribution being made in 1872, under the direction of the United States Commissioner of Fisheries.

In the first experiences of the culturists having the salmon in charge, the young were retained for several weeks and even months after the yolk-sac was absorbed, in many cases a heavy per cent. of losses occurring during the time. A general conclusion was arrived at that it was better to turn them loose much earlier, and this has become the usual custom.

In 1872 the operations for procuring the eggs of the salmon of the Sacramento River were begun by the United States Commission of Fisheries, Mr. Livingston Stone being deputized for this work. The principal results of his experiences benefiting the art of fish-culture were the method of impregnating eggs in considerable masses and freeing them from the growth of conferva by washing them in a mixture of sand and water. Mr. Stone attributes the origin of this suggestion to Mr. Woodbury, a fish-culturist of California, whom he had employed to assist him.

The transportation of the impregnated eggs eastward, and planting the young fishes in the eastern rivers in large quantities, which has been undertaken by the United States Commission of Fisheries, is an

* See pp. 259 and 282. † See note, p. 247. ‡ Referred to on a subsequent page.

extensive and novel work compared with all previous enterprises in fish-culture; and as far as the rivers of the Atlantic coast southward from the Connecticut are concerned, salmon will experience no change in conditions that will prevent a successful result, except possibly the great numbers of nets that may hinder the ascent of the salmon in the rivers at the spawning-season.

A summary of the very important results that have been developed in the culture of salmon, enhancing the interest of fish-culture, would begin with—

(1.) The official attention of States to the restoration of inland fisheries by artificial propagation, which began in Massachusetts in 1856, but took practical shape in 1866, when Dr. W. W. Fletcher, of Concord, was sent by the State of New Hampshire to obtain salmon-eggs from the Miramichi River of New Brunswick. In the same year the government of Canada began a like enterprise, and in Canada and the United States it has been continued and become a successful and more and more extensive enterprise yearly; and since 1872, under the auspices of the United States Commission of Fisheries, an extensive distribution of this valuable species has been carried out.

(2.) In the culture of this species by the Canadian government and the State of New Hampshire, the first application in America of the artificial propagation to a commercial fish of wide demand and extensive sale in the market was instituted.

(3.) An improved method in impregnating, resulting in the fertilization of almost the entire quantity of eggs, and that is essentially an American method; as in the so-called dry method in Europe, in all instances it is provided that water should be used, though in small quantity, while the method first used by Mr. Atkins, and afterward by many fish-culturists of the country, makes no application of water until after the eggs and milt have come thoroughly into contact.

(4.) Mr. Atkins's manner of obtaining seed-fishes by purchase through the whole of the period of immigration into the rivers prior to spawning and preserving them in ponds, is an original method for obtaining an unlimited quantity of eggs, not, I believe, before adopted in any country. In Switzerland living salmon have been transferred to new locations for natural spawning, or those about to spawn have been transferred for a short time to ponds, and the eggs taken; but as far as we can learn, Mr. Atkins was the first, at least on a large scale, to secure salmon in the spring, on their entrance into the river, and keep them for four or six months.

(5.) The arrangement by Mr. Atkins of troughs having trays placed at a distance above the bottom was a decided advance in apparatus, from the facilities afforded in manipulation of the eggs and removal of sediment.

The shad.—In 1867, it was determined by the commissioners of some of the New England States to attempt the restoration of the shad by artificial propagation, and the aid of Seth Green was obtained in the matter. He began his experiments at South Hadley Falls, on the Connecticut River, using the ordinary methods and apparatus in trout-hatching, which failed entirely to answer the purpose, because of the low specific gravity of the eggs and the coldness of the water used.

He then attempted to hatch them in floating boxes with wire-cloth bottoms, which proved for a long time failures, because of the difficulty of producing a current inside of the boxes that would keep the eggs in motion, until happily he tried the experiment with a box having the bottom tilted at an inclination toward the current, when he found the eggs were gently and continuously stirred by the entering waters, and the proper construction of apparatus indicated.

The quantities of young shad released into the river made a considerable impression on the fisheries three years afterward.

This seems to have been the first attempt to artificially fecundate and hatch the eggs of any species of this family, (*Clupeidæ*,) which contains species affording a very large proportion of the resources represented among the commercial food-fishes of the world, including the Astrachan herring of Russia, shad, alewife, herring, sardine, anchovy, menhaden, sprat, &c. The three first named are anadromous, and for these only, in the present state of fish-culture, will the art be available.

There has been no instance in the history of fish-culture where its application to the restoration of a species has so quickly and certainly afforded evident results as in the experiments of Seth Green upon the shad of the Connecticut River. Mr. Green continued his work the succeeding year, using the same model of box, which has not been improved upon since, though experiments with other models have been made by other fish-culturists on the Merrimac and Androscoggin Rivers. In 1869 he began on the Hudson River, under the auspices of the State commission, and a yearly increase of the species has resulted.

In 1871 he successfully moved a quantity of shad to the Sacramento River, California, and in 1873 the United States commission transferred a large number to the same river. A few have since been taken in the river, and the State commissioner thinks that others have been captured, and the fact concealed, on account of the penalty imposed upon any one taking them during five years after their first planting in the Sacramento.

The New York commissioners have had considerable numbers put into the Genesee River of Lake Ontario, and an extensive distribution into the tributaries of the Ohio and Mississippi Rivers and great lakes has been carried out by the United States.

The hatching of shad is prosecuted each year by Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, and by the United States commission. Full references to these State and national operations will be found elsewhere in the present report.

The progress in the history of fish-culture in the United States resulting from its application to the shad may be summed up as—

(1.) The foundation of a hatching-establishment by a State. Though a permanent building or even location is not an accessory of shad-hatching, still, the ownership of apparatus and the continuance of its use from year to year in the waters of a State are very properly to be considered as the founding of a hatching-establishment, and in this Massachusetts took the lead in 1867.

(2.) The shad-box invented by Seth Green was an advance of very great consequence, not only because it made it possible to increase the shad, its most important result thus far; but because it is adapted to, and in fact suggested the possibility of hatching the striped bass, and it was also found by Mr. Stone to be quite convenient in bringing forward the eggs of the California salmon when his hatching-house was found to be filled and plenty of eggs still to be obtained.

(3.) In the fact that young shad are delicate and with difficulty kept alive during transportation, the large amount of experience that has been brought to bear in their extensive distribution has led to improvement in method and in a more explicit knowledge of the needs and requirements of young fishes during transportation.

The white fish.—In November of 1857 Mr. Carl Muller, of New York, and Mr. Henry Brown, of New Haven, (see page 534,) having received from the State of Connecticut certain protective interests in Saltonstall Lake, near the city of New Haven, began a system of operations for stocking it with fishes, and the wall-eyed pike of the Ohio, the salmon-trout, and the white-fish of Lake Ontario were all transferred to the waters of the lake by means of eggs procured and impregnated artificially.

The account of the operation indicates a rather crude knowledge and method in the art of fish-culture, and it is probable that why a small proportion of eggs was hatched. The estimates of the number of eggs are very large. They were packed in moist sand and placed in the bed of the stream on their arrival, the white-fish eggs on a sandy shoal of less than three feet depth. The presence of young fish in great numbers in the following March and April was believed to result from the eggs, though the exceedingly common error on the great lakes of mistaking the schools of small cyprinoids for young white fish, which they very much resemble, except in the absence of the adipose dorsal, may have been repeated here.

In the fall of 1858 the experiment was renewed. There has been no reference made to any permanent results from this experiment in the reports of the State commissioners.

A more successful series of tests were begun in 1868 by Seth Green and Samuel Wilmot in applying artificial culture to this species, and in the succeeding year by Mr. N. W. Clark, of Clarkston, Mich. They were found to be very delicate and difficult to hatch in the first few years of experimenting, but methods were perfected that made their production as certain and with losses nearly as small as in other species.

The necessity of production of immense numbers in attempting to multiply the market species of fishes established the fact that the apparatus used in trout-hatching had to be extended over a wide area to accommodate them. The culture of the white fish and the salmon-trout induced modifications of apparatus at the New York State hatching establishment.

In 1872 wire-cloth trays were introduced within the troughs, placed one above another, four in depth. These trays were made of double lath on the sides and single on the ends, so that the current in the troughs passed through the narrow spaces at the ends, washing both the upper and lower sides of the wire-cloth on which the eggs were placed. A large supply of water was afforded each trough. The ordinary bed of gravel remained at the bottom of the troughs, in which the young fish were allowed to rest and hide themselves during the greater part of the yolk-sac period.

This apparatus was in some respects superior to that of C. G. Atkins, in the fact that it not only afforded facilities in manipulating the eggs, but afforded economy of space.

In 1872, at the New York State hatching-house, a new device was invented (perfected in 1873) by Marcellus G. Holton, of Seth Green's staff, to obviate the defects of the ordinary graveled troughs, and even of the improved trough. The arrangement of wire-cloth trays within troughs afforded a ready manipulation of the eggs, and a better opportunity for removing sediment and the omnipresent confervoid growth, (*Achlya prolifera*,) but did not afford in a sufficient degree the great desideratum of economy of space.

This apparatus (see plate) consisted of an outside case or box of wood, with a pipe conducted from a reservoir of water into the bottom, and the top of the case being below the source of supply, the water, of course, filled and overflowed at the top; within this case a series of wire-cloth trays were fitted, placed one above the other, from seven to eighteen in a case; and in the largest size not more than eighteen inches square, and containing about 18,000 white-fish eggs to the tray, so that in a space about 4 feet in width by 8 feet in length, 2,000,000 of white fish may be hatched, while at the very least twenty-five of the ordinary graveled troughs would be required for this number of eggs, filling the space of a very large hatching-house.

In 1873 a device to accomplish like results was made by Mr. N. W. Clark, of Clarkston, Mich., and patented in 1874. (See plate.)

This arrangement employed the troughs, but divided them into compartments by means of water-tight partitions or bulkheads; into each compartment a box containing a series of trays filled with eggs is placed and covered with a pan of perforated tin, upon which the water falls and descends through the perforations upon the screens and eggs beneath, passing through all and escaping at the bottom, afterward flowing over the partition upon the cover of the next box, and so throughout the series of compartments until it escapes through the waste-way at the end of the trough.*

By this arrangement a very small quantity of water is required for a very large number of eggs, and all the advantages of handling and removal of sediment and considerable economy of space are afforded.

Another combination of the trough and tray methods is in use in California, devised by Mr. John Williamson, of the California Acclimatizing Society. This is very similar to the one just described, except that the flow of water through the screens and eggs is from below instead of from the top. This model was not the result of work in white-fish hatching, as in the case with the two first mentioned.

An experiment was made by Mr. N. W. Clark in the hatching of white-fish eggs, which were laid in singlelayers of woolen cloth stretched on very thin frames of wood, packed in a box imbedded in sphagnum moss within a refrigerator and the whole kept at a temperature a little above the freezing-point by ice. The eggs are left entirely undisturbed after they are first arranged, and the only care on the part of the attendant is to keep the temperature above the freezing-point. The presence of dead eggs does not seem to contaminate the living ones in this condition, and very little confervoid growth appears. A quantity of eggs carried forward in this manner through the winter appeared to be in excellent condition, development progressing slowly, and a few taken from the cloths and placed in spring-water hatched out within a short time as well-developed embryos. If this method, after full and thorough trial, should prove successful, it would make the work of hatching a matter of neither effort, care, or expense. It has been a matter of too short experience and of experiment on too small a scale to warrant its positive success.

An improved case for the carriage of eggs long distances by railroad is another device perfected by Mr. N. W. Clark in 1872. It is a modification of the ordinary case containing circular cups, the cups being square, and in this form economizing space very much. The cups of tinned iron, about four inches square and two inches high, rest in trays, with low partitions forming low compartments that retain the bottom of each cup and hold it solidly in place. The trays are set within a square tin box, in which they fit with moderate tightness, and are placed, when containing the cups, eight or ten in the box, one above the other; this box is set within another box of tin large enough to leave an open space on all sides, to be filled with sawdust; a tube is inserted through the bottom of the inner box, piercing the bottom of the outer one, so as to permit communication with the air on the outside; the whole is then placed for protection within a strong wooden box, in the bottom of which is a frame resting upon stiff springs which relieve the

* For full description see plate and explanation.

eggs from heavy jarring; rubber or cloth bumpers on the sides of the box prevent lateral swaying and jolting. A cover is fitted to the inner box, which may then be covered with sawdust to the level of the higher outer one, when the cover of this is to be shut down. The outside wooden box is fitted with handles and with a tight lid on hinges, which may be locked. Small auger-holes are bored through the outer or packing box and air may be admitted to the whole interior of the egg-case through the tube referred to in the bottom, the cups being pierced with small holes, so that when in place they are directly over circular openings in the trays and a communication of air is established throughout.

The eggs may be packed in moss, in the ordinary manner, in the cups which experience seems to prove to be the best manner for long journeys.

The method of Mr. Atkins in shipping salmon-eggs packed in moss, but with pieces of mosquito-netting laid above and below the eggs, is a great convenience in unpacking them, and could just as well be applied in the cups. This, though less simple than the ordinary egg-carrier, is sufficiently simple for practical purposes, and possesses most important advantages for carrying eggs long distances and over rough roads, the small area of surface within the boxes preventing any tendency of the eggs to slide together at one side; the square boxes resting in trays are put together in much more compact form than the cylindrical boxes embedded in moss, and the springs beneath the boxes of eggs are of course an important addition.

Mr. Clark believes the hatching-apparatus in the refrigerator to be as well adapted for the carriage of eggs as for hatching them.

The use of surface or brook water in any permanent establishment seems to have been first employed by Mr. Samuel Wilmot, of New Castle, Canada, the greater number of hatching establishments using spring-water.

In the hatching of white-fish, Mr. Clark has contended for the use of brook-water in preference, because of its lower and evener temperature throughout the winter, and the consequent retardation of the hatching of the fish which he has contended is an essential provision in nature to their welfare, and that the hatching them two months or more previous to the natural time under artificial conditions is a mistaken method that will not result in the maturing of any considerable numbers of the cold waters in which they are released. Though this view has not been established by practical observation, yet it raises a question of considerable importance that merits a full discussion of its character and bearing on the practical work of fish-culture. A few extracts from a letter of Mr. Clark to the board of fish-commissioners of the State of Michigan, will advance his arguments in favor of brook or surface waters in preference to spring-water. Mr. Clark began his experiments with white-fish in 1869, hatching a small percentage of the eggs he procured:

"In November, 1870, I started again for Ecorse for the purpose of procuring more spawn. Mr. George Clark, at his fishery, very kindly rendered me all the aid in his power, furnishing the parent fish for the purpose of trying further experiments in this new enterprise. I succeeded in obtaining all the spawn needed for further trial, but he was so anxious to make it a success that he sent his man to me with an extra lot which he thought might be in better condition. I succeeded in hatching a much larger proportion of them than the year before, but raising them with artificial food was attended with no better success. This second effort and failure led me to investigate the cause, and after much thought I came to the conclusion that if we ever succeeded in making this branch of pisciculture a success, we must study the principles of nature more than had ever been done before. I became fully satisfied that by arranging so as to use water taken from a pond or lake entirely frozen over, it would retard the development of the eggs to the time required by nature, which proved by subsequent experience to be about April 1. I then consulted Messrs. George Clark and John P. Clark, and made known to them my convictions, and so strongly were they convinced that I had struck the key-note to insure ultimate success that they proposed to furnish all the necessary materials and a portion of the labor to enable me to go on and erect a large hatching establishment. This was located about 80 rods below the spring where we had been experimenting the two years previous with the unsatisfactory results above stated. This location was supposed to be a sufficient distance below the main spring, so that by damming the water and raising a pond it would freeze over and remain so during the period of incubation.

"Our views proved to be correct, as the 500,000 of eggs which we placed in the hatching-boxes November 15 of that year were preserved in fair condition, and with one-quarter less labor in caring for them than formerly. They did not commence to hatch until April 1, and it was estimated that we succeeded in hatching at least 50 per cent. of the eggs we had taken four and one-half months previously at the fishery of George Clark.

"Of these young fry, some 100,000 of them were put in Detroit River, at or near his fishery place, and no doubt at this time they are thriving finely in the waters of Lake Erie, which abounds with abundant natural food for them, and in a year or two more they will doubtless return to the same place where they were deposited. The balance of them we placed in three small lakes in Oakland County, some of which have been seen within the last few months, doing finely.

"This experiment proved so great a success that again, the next November, 1872, through the encouragement of the Messrs. Clark and the United States Fish, commissioner, I doubled the capacity of this hatching-house and procured 1,000,000 of the ova from the same grounds, and proceeded as before with some improvements I made in the *modus operandi* of hatching about February 20. Mr. Milner, deputy United States commissioner, arrived at this place for the purpose of aiding me in packing and shipping a lot of the ova, which were then in an advanced stage of incubation. We estimated from actual count that 66 per cent. were in such an advanced state that they were secure from any further mortality. We then shipped to San Francisco 216,000 in the most perfect condition.

"About March 10 I received an order from the commissioner at Washington to send the same number again to the same place, which I should have done, but from the fact that the eggs had become so far advanced that I felt quite confident they could not be transported so great a distance successfully, and only sent 116,000, which I am most happy to have heard arrived in excellent condition. Soon after this the weather became much warmer and the ice all thawed from the pond, and by the 20th of the month the eggs then remaining in the troughs commenced hatching. The water had then risen to a temperature of 45 degrees, which sudden change caused the eggs to turn white, and soon all were worthless. Quite a large number had already hatched out, and I removed part of them to the same lake where Mr. George Clark and myself had put in a large number the year before, and placed about 25,000 in a small lake at Clarkston Village.

"This sudden change in the condition of these eggs I cannot account for, only from the fact of the change in the temperature of the water at this late stage of their development. I am fully satisfied that if the ice had remained in the pond as late as the previous year I should not have lost two per cent. from the time I made the last San Francisco shipment.

"This experience satisfied me that spring-water, although it may not be used until it advances a long way down from its source, is not the place to hatch white-fish. Although this pond was clear from ice March 15, the ice remained in our lakes in this region until May 1.

"This species of eggs, and especially those not good and not perfectly impregnated, placed in spring-water at a temperature of 46 degrees (which is about the same as all good springs) in winter, will start out a growth of vegetable fungi more than four times faster than if placed in water at 33 degrees, which is the temperature of ice-water, and it is next to impossible to employ help enough to pick out the dead eggs (when in spring-water) when you have over a million, as I had the last two seasons.

"Even in ice-water last winter, which preserved the eggs much longer than in spring-water, it required from eight to ten persons to keep them in fair condition, and then sometimes they were necessarily left too long in an unfavorable condition.

"These facts are conclusive proof to my mind that the ova of white-fish should be kept entirely away from the influence of spring-water, or any water which will be liable to change during incubation, and all houses where white fish are to be hatched should be constructed upon some lake or pond that freezes over early and does not thaw out until April 1.

"It is stated as a reason why spring water is better for hatching fish eggs than lake water, that it is generally more free from sediment, some kinds of which are highly detrimental to the successful hatching of the fish ova. Whereas our inland lakes freeze over early in the fall, and are not free from ice until late in the spring. This ice is perfect protection against any agitation of the water, and gives an opportunity for any sediment that may be in it to settle to the bottom, where it must remain until spring, and until the eggs are hatched and distributed. Consequently the water in all of our inland lakes is, during winter, as clear as crystal.

"You also wish me to give my views in reference to using Detroit River water. To this I will frankly say that I should much prefer it to any spring water in this or any other State for hatching white fish. But there are some objections which arise in my mind even to this water. I am aware that this species of fish are natives of our great lakes and rivers, and consequently it would be supposed that this water must agree with them, and that success would be certain if this water was used. But has it not occurred to all persons who have given this subject much thought that much the largest proportion of these fish run to the shoals of those lakes during spawning season to deposit their ova? These shoals are the first to freeze over in the fall and the last to thaw in the spring. This keeps at nearly the same temperature during incubation. Although it may be said that during their migration from Lake Erie to Lake Saint Clair some deposit their spawn in the rivers; it is not very probable that much of it is hatched.

"I am aware that many hatch in and about the ponds where the fishermen preserve their fish for winter use. This tends to prove that the shoals are the place where they hatch most largely, as the ice remains in these ponds much longer in the spring than in the strong current in Detroit River.

"If water is used from this river it must change in temperature many times during the winter, as it is well known that the ice leaves the river quite often during the four-and-a-half months of the period of incubation. No one can gainsay the fact that in the hatching of fish ova, if the water is of a perfectly even temperature, it will be attended with more favorable results than when frequently changing, from any cause, even if such change is not more than two or three degrees. Is it not also a fact that the ice frequently leaves the lower part of Lake Saint Clair early in March? If so, would not the westerly winds roll the water in the upper part of the river? This sediment would be deposited on the eggs, and in consequence of its fine, clammy nature, would be injurious to them. I noticed this was the case in a little experimental arrangement of A. M. Campau, some two years since, where this water was used. I examined these eggs several times during this process, and found a fine, clammy substance accumulating on them. They were gradually dying, and I do not think any were hatched. These eggs were taken from our hatching-boxes, and were in perfect condition, as they were so far advanced in development that the embryo fish could be plainly seen with the naked eye. For these reasons I am forced to the conclusion that there is more suitable water for hatching this species of fish-eggs than the Detroit River.

"I wish, however, to have it distinctly understood that salmon, salmon-trout, and brook-trout should be incubated in pure spring-water, as they will hatch the latter part of January or early in February. They have an umbilical sack from which they derive their subsistence, and which takes about fifty days to absorb. They do not require food during this period. After this, by feeding them a few days, they will do to turn loose in water adapted to them, where they will find their own food. For these reasons it would be very desirable if your commission could find a location where both spring and lake water could be supplied in sufficient quantities to insure the success of breeding both kinds.

"Most respectfully and truly yours,

"N. W. CLARKE.

"*Clarkston, September* 13, 1873."

In conclusion, the advantages afforded American fish-culture from the cultivation of the white-fish as they have just been enumerated: These are; (1) more careful and perfect methods, resulting from the experience in the culture of the most delicate and difficult species whose propagation has been attempted by culturists; (2) the perfection of three forms of apparatus for hatching fish-eggs, embodying the important improvements of facility in handling the eggs and removing sediment and confervæ, and greatly economizing space; (3) the contrivance of a superior case for the carriage of eggs; and, besides, a possibly successful, entirely new method in the hatching of eggs and the discussion of and practical tests of conditions of water suitable to the eggs of a species that we are not (at any rate thus far) able to supply with food.

The Otsego bass.—Another species (?) of white-fish (*Coregonus otsego*) has been successfully propagated at Cooperstown, N. Y. A large quantity of eggs were impregnated in the autumn of 1871, and in the following March several thousands of young fishes were set free in the lake. In 1873 a larger number were released, and a quantity of eggs put into the hatching-troughs.

The salmon-trout.—In the fall of 1857 and 1858 a large number of eggs of salmon-trout were obtained for Saltonstall Lake in Connecticut from Lake Ontario. The enterprise is referred to more fully on page 534.

A minor experiment in hatching salmon-trout, or Mackinaw trout, (*Salmo namaycush*,) was made by Mr. Samuel Wilmot, of Newcastle, Canada, in 1868. He also obtained a hybrid between a male *Salmo salar* and a female *S. namaycush*. The next published records we have of experiments are by Seth Green and by N. W. Clark in 1870. Mr. Clark's was with but a few eggs. In an address before the legislature of Michigan, he refers to the fact of having young salmon-trout on exhibition.*

The quantity of eggs taken by Seth Green that year and hatched was very large; and the fish proving to be a great favorite among the people of the State, he has continued to breed it on a large scale, and it has been widely distributed throughout the State.

The greatest drawback in the culture of this species is the difficulty and danger attending the procuring of the eggs.

The spawning-places of the fish in the region of the hatching-houses is in the open lake; and the time when the ova are ripe is in October, when there are frequent storms, so that going out in an open boat to the nets is a task of hardship and danger, and has resulted, in a late instance, in the loss of six men, one of them Marcellus Holton, an accomplished fish-culturist and the inventor of the Holton hatching-box. There are however, points on the lakes accessible by steamer, though not contiguous to the breeding-establishments, where the salmon-trout spawning-grounds are near the shore, and even entirely land-locked from wind and sea.

The striped bass.—In connection with the work of the United States Commission of Fisheries, a successful experiment has been made which bids fair to be one of great importance in connection with the history of fish-culture. In 1873, Mr. Marcellus Holton, one of the men who were lost while obtaining the spawn of the salmon-trout on Lake Ontario, was employed by the United States Commissioner in the work of shad-propagation on the Roanoke River, North Carolina. While at the fisheries near Weldon, he procured and impregnated the spawn of the rock-fish, (*Roccus lineatus*,) and succeeded in hatching then. The appended letter gives his method and the extent of his success:

"WELDON, *May* 22, 1873.

"DEAR SIR: I think, from indications observed, that the rock-fish spawn in the day-time. We find the eggs are much lighter and more delicate than those of the shad. We have afforded them similar treatment, using the shad-boxes, and I think it is evident that they hatch a little sooner, but do not feel sure on this point, as I was obliged to move the boxes, while containing the eggs, below the falls, and the water was very rough while passing the rapids. I was compelled to move them because of the rapid rising of the river, which threatened to flood us out on the low shore, where we were encamped. It is quite possible that this hatched them prematurely. In twenty hours after impregnation, and before they were exposed to the rough water, the fish within the egg showed signs of life, and in forty hours kicked lively.

* Pisciculture, or Fish-Farming: an address before the legislature of Michigan, &c. Delivered at Lansing, February 28, 1871, by Hon. N. W. Clark, of Clarkston, Mich. Detroit, 1871. Page 21.

"They escape through the meshes of the wire-cloth as fast as they hatch. It will take at least twenty-four wires to the inch to hold them, and I think the eggs require less current than shad-spawn.

"Yours,

MARCELLUS G. HOLTON.

"Prof. SPENCER F. BAIRD,

"*Washington, D. C.*"

Mr. Holton, in another letter, reported the eggs obtained from two spawners at 120,000, and out of these he estimated the number hatched at about 70 per cent., or 80,000 young fry. The female parents weighed six and eight pounds. The eggs were nearly equal in size to those of a shad; the newly-hatched fry were somewhat smaller.

The fact that the ova were non-adhesive, unlike most of the percoid fishes that have been dealt with, was a matter of surprise. The weight of the spawning-fish is somewhat less than has usually been attributed to rock-fish in spawning-condition. If localities can be found where rock-fish may be taken in sufficient numbers in the breeding-season, the increase of this species is probably as sure to be effected as that of the shad has been.

We append a list of the species already referred to, and also of those with which small experiments have been made, with varying success, in the United States. The perch, (*Perca flavescens;*) the wall-eyed or glass-eyed pike, (*Stizostedium americanum;*) the rock-bass, (*Roccus lineatus;*) the salmon, (*Salmo salar;*) the California salmon, (*Salmo quinnat;*) the brook-trout, (*Salmo fontinalis;*) the Pacific coast brook-trout, (*Salmo iridea;*) the Utah trout, (*Salmo virginalis;*) the land-locked salmon, (*Salmo sebago;*) the salmon or Mackinaw trout, (*Salmo namaycush;*) the lake white-fish, (*Coregonus albus;*) the Otsego bass, (*Coregonus otsego;*) the lake-herring, (*Coregonus clupeiformis;*) the grayling, (*Thymallus tricolor;*) the shad, (*Alosa sapidissima;*) the alewife, (*Pomolobus pseudo-harengus;*) the common sucker, (*Catostomus communis;*) the shiner, (*Stilbe crysoleucus;*) the corporal or chub, (*Semotilus corporalis.*)

Collating from numerous authorities on fish-culture in Europe, we are enabled to give the following list: The burbot or *la lotte*, (*Lota vulgaris;*) the salmon, (*Salmo salar;*) the sea-trout, (*Salmo trutta;*) the river-trout, (*Salmo fario*); the lake-trout, (*Salmo lacustris;*) the *ombre chevalier* or *röthel*, (*Salmo umbla;*) the charr, (*Salmo alpinus;*) the hucho, (*Salmo hucho;*) the laveret, (*Coregonus laveratus;*) the fera, (*Coregonus fera;*) the maræna, (*Coregonus marœna;*) the *palée*, (*Coregonus palea;* the *Coregonus albula;*) the grayling, (*Thymallus vulgaris;*) the carp, (*Cyprinus carpio;*) the crucian carp, (*Cyprinus carassius; Cyprinus kolfarii;*) the tench, (*Tinca vulgaris;*) the white-bream, (*Abramis blicca;*) the ablette, (*Cyprinus alburnus;*) and the sterlst, (*Acipender ruthenus.*)

Of the hybrids claimed to have been produced artificially, which but few seem to have attained maturity, we give the following list:

EUROPEAN SPECIES.

Male.		*Female.*
The salmon, (*Salmo salar.*)	with	The river-trout, (*Salmo fario.*)
Do., do.	do.	The lake-trout, (*Salmo lacustris.*)
Do., do.	do.	The *ombre chevalier*, (*Salmo umbla.*)
(?) *Ombre chevalier*, (*Salmo umbla.*)	do.	The salmon, (*Salmo salar.*)
The river-trout, (*Salmo fario.*)	do.	Do., do.
Do., do.	do.	The *ombre chevalier*, (*Salmo umbla.*)
The *ombre chevalier*, (*Salmo umbla.*)	do.	The river-trout, (*Salmo fario.*)
The lake-trout, (*Salmo lacustris.*)	do.	The salmon, (*Salmo salar.*)

AMERICAN SPECIES.

The white-fish, (*Coregonus albus.*)	The salmon-trout, (*Salmo namaycush.*)
The alewife, (*Pomolobus pseudo-harengus.*)	The shad, (*Alosa sapidissima.*)

The advances made in the art of fish-culture by its adoption in this country are now extended by its application to a number of new species.

In the family of *Clupeidæ* nothing seems to have been attempted in Europe, while in America the culture of the shad (*Alosa sapidissima*) is one of the most extensive and successful efforts in fish-culture, and that of the alewife (*Pomolobus pseudo-harengus*) has been experimented upon with success.

In the genera of *Salmo*, *Coregonus*, and *Thymallus* there is entire similarity of condition between American and European species, though the species are different, except in the case of *Salmo salar*.

In apparatus there are several advances. Though in considering the shad-box (see plate) we find the floating-box with wire-gauze in use in the old world for years,* still its inclination to the current, in the manner of Seth Green's patent, is an improvement in producing a complete and continuous circulation of water.

The tray-methods of Holton, of Clark, and of Williamson (see plates) are of great importance in economy of space, in the facility for manipulation of the eggs, and, in saving of expense, because smaller buildings are sufficient for the accommodation of apparatus, and from the compactness of the apparatus more labor can be accomplished than with the extended trough method.

Improvements in egg-carriers and in vessels for transporting young fishes have been referred to on another page.

The advance made in methods of impregnation and care of ova are the results of continued experience and study. The so-called dry

* See Vogt's Essay on Fish-Culture. Translation in Report on the Artificial Propagation of Fish, by G. P. Marsh, Burlington, Vt. Page 41.

method of impregnating ova in Europe and the more properly dry method of America are the most essential improvements, as they have increased the results from a given number of ova in a large ratio.

It will be observed that advances have been made both in apparatus and in methods by the extension of the application of the art to new species of fishes. Seth Green's shad-box was the result of the experiment in hatching shad. The tray-methods of Holton and of Clark were the result of attempts in hatching the lake white-fish, a species that at first gave discouraging results to the efforts of those who attempted it. An improved knowledgê and system for transporting live fishes resulted from the distribution of shad; a species that was found to be exceedingly delicate, and requiring great care in transportation.

The American system of dry impregnation was discovered in the salmon-breeding establishment of C. G. Atkins. Different conditions and necessities arise in the experiments with each species, and new ideas more or less applicable to other species are developed.

The application of fish-culture to species having adhesive eggs has scarcely begun in this country; a few experiments with the glass-eyed pike, the perch, and with a species of the smelt are all that have been recorded. Experiments with one of the sucker-family, *Calastomidæ*, and with a cyprinoid, are referred to without stating the character of the eggs, which were probably adhesive. The eggs of the ale wife have proved adhesive for a considerable time during and after impregnation, but are not to be included in permanently adhesive eggs.

In Europe there has been a great deal done with this group of fishes; the carp, of several species and varieties, engaging a great deal of attention.

The value of this fish as an accession to the number of food-fishes of the United States is a matter of importance. The estimates of their qualities as table-fishes are very varying and contradictory.

Those who are familiar with the food-fishes of the fresh waters throughout Europe assert that this arises from the difference in quality of different varieties and species; and that while some of them are excellent and palatable, others are very inferior. Among those of superior quality are the *Cyprinus carpio*, var. *nudus* and var. *rex-cyprinorum*, the spiegel-carp. The first variety is destitute of scales, having a velvety skin that enhances the table-qualities of the fish. The latter has a row of scales near the dorsal line, and another near the ventral margin. The former is found chiefly in the Lower Danube, and is spoken of as a species very superior in flavor. Among the more inferior ones are *Cyprinus carassius*, the crucian carp, and the hybrids with this and other species.

It is claimed by Francis Francis, editor of The Field, London, England, land, that the carp attains much better qualties in flavor, as a game fish, in large rivers than it does in ponds.*

* Fish-Culture a practical guide to the modern system of rearing and breeding fish By Francis Francis; Pisc. Div. Accl. Soc. of Great Britain. London, 1865.

They are especially valuable because of their adaptation to ponds and even stagnant waters attaining a high degree of heat. In addition to their value as food for man, they will be of great utility in affording a supply of food for those piscivorous fishes it is desirable to propagate; being, it is said, in a considerable degree herbivorous, they can exist in large numbers in the ponds with black bass, glass-eyed pike, or the muskellunge, without reducing the original food of these fishesin the waters, and, of course, increasing it in a considerable degree in the presence of their own young.

The procuring of cheap food for the fishes in the troughs, in the nurseries and the ponds, has been obtained, to a considerable extent, in this way in Germany and Russia, and, it may be, would be found to answer for our brook-trout.

Another fish, the introduction of which is desirable but whose propagation may be left entirely to nature, like that of the black bass, is the gourami, (*Osphromenus olfax*,) a species that is prolific, attains considerable size, of most excellent flavor, and is especially advantageous from the the fact that it is adapted to the warm water-ponds of the warmest temperate and subtropical regions. It can be readily introduced in the southern portions of the United States from China or from Algiers; in both countries it has been introduced, originating in the Malaccan Islands. (See Department of Agriculture Report, 1866, p. 417.)

Although the loss of eggs before hatching has been reduced to an inconsiderable minimum by means of improved methods of impregnation and care during hatching, still there are many things to be accomplished before any high degree of perfection in the culture of fishes will be attained. One of the most important desiderata is the prevention or cure of the omni-present confervaceous growth, (*Achlya prolifera*.) Numerous experiments have been tried by men skilled asfish-culturists and chemists without accomplishing anything that receives general application and approval. The application of salt-brine has been advocated.* Experiments have also been made with solutions of acids and alkalies.

The apparatus for packing eggs in boxes covered with ice and moss, so that the low temperature may retard the growth of the confervæ, has been described on page 547.

At Mr. N. W. Clark's hatching-house the eggs of the white-fish during the past winter have been daily rinsed free from adhering sediment and the developing parasites by agitating the trays containing the eggs in a shallow pan of water. This, though it may appear a rather violent treatment of the eggs, has been kept up throughout the winter without apparent injury, and a large percentage of young fishes has resulted from the eggs thus treated.

A uniform system in the estimation of the numbers of eggs, and consequently a more reliable estimate of the percentages hatched, has been

* On page 174 will be found an account of the method employed to clean the eggs of the *Salmo quinnat* from this foul growth by means of sand and water.

referred to on page 442, under the head of "The artificial culture of the shad."

In order to make the progress definite and rapid, a continued series of systematic observations of the work in the hatching-house is essential. And these should not be confined merely to what many would consider the more practical points in the different processes, but should embrace, in addition many of the minor conditions and phenomena. For instance, in the rather full memoranda of each day's work in shad-hatching in the New York State reports, we have the date, number of shad taken, the number of ripe females, the number of eggs, and the temperature of the water in the morning and at night. From a long series of these observations carefully carried on through a number of years, we might anticipate the working-out of many of the relations between temperature of the rivers and the ascent of the shad; possibly, too, the relation of the ripening of the spawn in the ovaries of the fish to the temperature, in which it is quite probable some very interesting facts may be developed. For example, nearly all shad-fishermen have observed the fact that female shad with full roes are taken to the very end of the fishing-season, and we do not absolutely know that all the mature female shad ripen the ova and spawn before returning to the sea. The addition to the memoranda of the number of ripe male fish obtained would have been of value, as there is evidence indicating that a considerable number of the males are ripe and begin losing the milt before many females are ready to spawn; and toward the close of the season it is often difficult to obtain a sufficient number of males to impregnate the spawn; the record of the number of ripe males obtained would throw light upon this point. In the Massachusetts reports are given the number of fish taken at each haul, and the time of day when the haul was made. These afford data for a knowledge of the movements of the fish while in the rivers, to what extent they are nocturnal, and the like. Among other things, a record of similar character in a trout-hatching house might result in affording an accurate comparison of the vigor and fertility of eggs from domesticated fishes and from wild ones, together with other changes in the fish, as to time of spawning and the like.

E—ALPHABETICAL LIST OF AMERICAN FISH-CULTURISTS AND OF PERSONS KNOWN AS BEING INTERESTED IN FISH-CULTURE.

1.—*Names of persons who are or have been practically engaged in fish-culture.**

Ainsworth, Stephen H., West Bloomfield, N. Y.

Axtell, F. F., Harvard, McHenry County, Ill.

* Corrections or additions, if sent to the United States Fish Commissioner, Washington, D. C., will be introduced into future lists, which it is hoped will more completely represent the statistics of fish-culturists.

Bacon, William, (Dexter, Bacon & Coolidge,) West Barnstable, Mass.
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Bond, Amos, Chicopee, Mass.
Booth, H. C., Charlmont, Mass.
Bowles, B. F., Springfield, Mass.
Bridgman, J. D., Bellows Falls, Vt.
Burnett, Joseph, Southborough, Mass.
Campbell, E. K., M. D., Saxton's River, Vt.
Campbell, Messrs., Mumford, N. Y.
Chandler, Fred., Alstead, N. H.
Christie, H. P., (?) Clove, Dutchess County, N. Y.
Clark, N. W., Clarkston, Mich.
Clift, W., Mystic Bridge, Conn.
Cole, A. P., Whitesville, Allegany County, N. Y.
Collins, A. S., Mumford, Monroe County, N. Y.
Comer, J. H. & Bro., Lake Tahoe Fishery, Lake Tahoe, Nev.
Comfort, Jeremiah, Spring Mills, Montgomery County, Pa.
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Drury, L. M., Canandaigua, N. Y.
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Glidden, O. F., Stoneham, Mass.
Goldsmith, Dr. M., Rutland, Vt.
Green, Seth, Rochester, N. Y.
Gridley, Robert, Saratoga Springs, N. Y.
Hagar, Mr. David, Wallingford, Vt.
Hammond, D. S., Elgin, Ill.
Harmon, George, Mumford, N. J.

Haywood, Levi, Gardiner, Mass.
Haywood, Walter, Fitchburgh, Mass.
Heyford, George O., Dixfield, Me.
Hilgen, F., Cedarburgh, Wis.
Hills, Mr., (Thomas & Hills,) Bergen, Cattaraugus County, N. Y.
Holmes, F. H., Norway, Me.
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Huntington, Dr. J. D., Watertown, N. Y.
Hurdick, Mayor, Williamsport, Pa.
Ingraham, E., Bristol, Conn.
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