the spawn was thrown into the water from the salmon caught by fishermen and sold to the canneries. As to catfish, I believe their importation to this coast was an error; and the board of fish commissioners who authorized their importation, if I remember rightly, came to the same conclusion. The fish which they destroy, however, are perch and dace and their spawn, which at one time were found in vast numbers in the Sacramento.

SAN FRANCISCO, CAL., *June* 8, 1887.

18.—THE EGGS OF FISHES.*

By Prof. McINTOSH, LL. D., F. R. S.

[Abstract of an introductory lecture delivered to the class of natural history in the University of St. Andrew's.]

It is but a short time since works devoted to the history of British fishes were devoid of allusion to any other mode of spawning than that by which the eggs of our marine fishes are deposited on the bottom of the sea. Indeed it was believed by most naturalists that the latter was the normal mode of deposition. As a consequence, some of the text-books at present in use either follow the latter view, or do not specially allude to the question.

The eggs of all fishes are produced in the ovaries, which are symmetrical organs lying beneath the vertebral column, and which at different periods of the year present various appearances according to the degree of development of the eggs. Thus in the quiescent condition of the organs their size is insignificant, while the fully developed ovaries of the codfish occupy a large space and weigh several pounds. At first the eggs are very small, but they gradually increase in size by imbibing nourishment from the ovarian follicles in which they are placed.

A feature not sufficiently insisted on in Great Britain is the fact that only a portion of the ovary in most marine fishes becomes "ripe" at a given time. This provision appears to be admirably suited for the increase of the fishes, a constant succession of the embryos being thus liberated, and time afforded for those of one stage to disappear from the surface of the ocean before those of the succeeding take their places. In America this condition has been clearly described in the report on the cod fisheries of Cape Ann,* by Mr. R. E. Earll; but the account does not seem to have come under the notice of Mr. William Oldham Chambers, who alluded to the subject a year or two afterwards.†

Mr. Earll observes that "the individuals [that is, the cod] do not deposit all their eggs in a single day or week, but probably continue the

* See U. S. Fish Commission Report for 1878, pp. 685, 714, *et seq.*

† "Fish and Fisheries," prize essays, International Fisheries Exhibition, Edinburgh, 1883, *p.* 187.

operation of spawning over fully two months." The result of this arrangement is that some of the American codfish begin to spawn in September, and some continue as late as June. The cod in our seas do not follow the same habit, though their spawning period extends on each side of the beginning of April. In the same way the period during which the eggs of the various kinds of skates are deposited is considerably lengthened.

On the other hand, such marine fishes as the lumpsucker (*Cyclopterus lumpus ?*) and bimaculated sucker, the salmon, trout, and most freshwater fishes seem to deposit their eggs within the limited period of a day or two, and consequently the development of the masses of eggs in the ovaries is more nearly simultaneous.

In general form the eggs of ordinary fishes are circular. On deposition they are usually invested by a single layer (*zona radiata*), though in some, as in the herring, there is another, namely, the vitelline membrane, which lies outside the former. The great mass of the egg is formed by the oval spherules of the food-yelk, which are separated by protoplasmic bands. Near one of the poles the protoplasm usually forms a lenticular area, the germinal disk or germinal area, and the smaller yelk-spherules in this region differ in character from those of the general mass of the egg. During development the eggs show partial segmentation, the process being chiefly confined to the germinal area.

While the circular form as just described is characteristic of the eggs of most fishes, we have a few marine types which deviate from the general rule, such as the glutinous hag (*Myxine glutinosa*), with its ovoid and fringed eggs; the goby, with its fusiform ova; the gar pike, saury pike, and flying-fish, which have long filaments attached to their eggs, probably for the purpose of fixing them to floating structures of any kind. Among other interesting types are the large eggs of the stickleback and the salmon tribe, and the almost microscopic eggs of the eel. The large ova of the salmon and trout are surpassed, however, by those of the siluroid genus *Arius*, found both in the Old World and the New (Ceylon and Guiana), the eggs being somewhat larger than a pea (5 to 10^{mm}.); but this is not the only remarkable feature in these fishes; for as Drs. Günther and Wyman and Professor Turner have shown, the large eggs are carried by the male in his mouth and gill-chamber until hatched, the small and almost granular palatine teeth making this possible without injury to the ova. He thus acts the part of a "dry-nurse," as also does the male pipe-fish (*Syngnathus*) and the sea-horse (*Hippocampus*), the eggs being borne by the male in a pouch on the under surface. In another siluroid fish (*Aspredo*) from Guiana, the remarkable exception occurs of a female fish interesting itself in the care of its young. The skin on the under surface becomes soft and spongy, and the eggs, which are deposited on the ground, adhere by simple pressure of the body over them, very much after the arrangement in the

Surinam toad. Only one other female fish shares with this one the distinction just noted, namely *Solenostoma*, an Indian lophobranch, in which the ventral fins, which are free in the male, coalesce to form with the integuments a pouch for the reception and hatching of the eggs. The entire group of the sharks and rays (*Elasmobranchii*), again, is characterized by the peculiar condition of their eggs, which are distinguished not only by their great size, but also by the fact that they are either deposited in horny capsules, or retained in the oviduct until hatched. The former takes place in the common rays, certain dogfishes (*Scyllium*), and sharks (*Cestracion*), and in the curious *Chimæra* and *Callorhynchus;* while the latter (that is, the production of living young) occurs in the rest of the sharks and in the torpedoes.

As already indicated, the prevalent notion among the older naturalists was that fishes of all kinds deposited their eggs on the bottom of the sea, and that extensive migrations were made for this purpose, the general impression being that the majority proceeded shorewards to deposit their eggs in the shallow water. This impression was probably due to the fact that the salmon, and perhaps the herring, followed this habit, the former proceeding up rivers and the latter selecting certain banks, often near land, covered with sea-weeds and zoophytes, or a bottom composed of stones and gravel; and it was assumed by the older observers that all marine fishes followed similar habits. Thus it was supposed that the cod, haddock, whiting, ling, hake, and other fishes frequented certain banks for the purpose of depositing their eggs, and that various flat-fishes, such as the larger turbots and soles, came from deep water to shallow water for the same end. Such conjectures, however, were found to deviate very considerably from the facts.

Among the earliest to notice that the eggs of certain marine fishes floated were the cod fishermen of the Lofoden Islands, off the coast of Norway. These Norwegians had noticed that what they called the "roe" of the codfish floated in the water on the great fishing-banks, and often at certain seasons to such an extent as to make the water thick. Prof. G. O. Sars, inspector of fisheries in Norway, to whom this remark was made, supposed that the fishermen had mistaken some of the lower marine animals for the eggs of fishes; for such a feature was in direct opposition to anything he knew of the spawning of fishes. The subject, however, was soon set at rest, for he proceeded in 1864 to the fishing-grounds off the Lofoden Islands, and captured in the tow-net immense numbers of the eggs of the cod floating at the surface of the sea. Next year, indeed, on a calm day, Professor Sars found the sea covered with a dense layer of floating spawn, so that with a sufficiently large net, he could have taken tons of it. This occurred over a celebrated fishing-ground, on which the cod were present in enormous numbers, so as to form what the fishermen called a "fish mountain." Professor Sars also found that the ova of the haddock floated, and among the eggs procured from the surface of the sea were some from

which young fish resembling gurnards emerged, and he correctly concluded that the ova of the gurnard followed the same habit as those of the cod and haddock.

The impetus given to such observations by the energetic action of the United States Fish Commission enabled the Americans to corroborate the discovery of the Norwegians in regard to the floating of the ova of the cod, which lately have been artificially hatched on a somewhat extensive scale on their coasts. The labors of Prof. Alex. Agassiz in the same country have further added to our knowledge of floating eggs, showing that the number of fishes in which this occurs is considerable. Thus the majority of the American flounders, certain kinds of wrasses (*Ctenolabrus*), a species of smelt (*Osmerus*), several species of *Cottus*, the cod, haddock, gurnard, shad, mackerel, and Spanish mackerel, a kind of dory (*Zeus*), and the frog-fish are among those which have floating eggs. The late Dr. Malm, of Gothenburg, further increased the list by discovering that the eggs of the plaice were similarly buoyant; and G. Brook has recently added to this category the eggs of the lesser weever. The very great influence which this floating of the tiny eggs exercises on the multiplication of the food-fishes will be apparent as the subject is further examined.

On the other hand, most fresh-water fishes (except the shad) deposit their eggs on the bottom, like the salmon, or on water plants, like the carp and pike; while other marine species, such as the herring, sprat, lumpsucker, and bimaculated sucker, follow a similar method. The number of marine fishes which are supposed to deposit their eggs on the sea-bed is yearly diminishing, while the ranks of those in which the ripe eggs are found to float correspondingly increase.

To come now to our own shores, and to confine our remarks to what is really the most important group of fishes, namely, the food-fishes, we find that early in spring the surface of the sea over the great fishing-banks (such as Smith Bank, off the northeast of Scotland, off Caithness), presents vast numbers of floating eggs of food-fishes, together with multitudes of the very young fishes provided with a yelk-sac, exhibiting various degrees of absorption. Some of the ova (as those of the haddock and gurnard) are larger than those of the cod, but they are few in number; while those of a fourth kind are smaller than any yet mentioned. When placed in a vessel of sea-water the eggs persistently float on its surface, descending but a very little when the jar is rudely shaken. Even after a protracted journey only the dead eggs roll on the bottom of the vessel, while all the floating eggs are living. Moreover, the eggs were removed from the cod itself and carried from Smith Bank to the marine laboratory at the harbor. On arrival, these floated at the surface of the vessel. On transfering them to a large jar and turning on a tap of sea-water a great change occurred. The ova in a few minutes lay on the bottom. Microscopic examination subsequently showed that the edge of the germinal area was disintegrating, free pro-

toplasmic processes and separate cells occurring all round. The cause of this sudden change was doubtless the impurity of the water (for the proper apparatus had not yet been fitted up), the metallic pipe (block-tin) containing an opaque whitish deposit which speedily killed the ova. The addition of methylated spirit in the same way sends all the eggs and embryos to the bottom. Professor Sars, indeed, mentions that if the eggs of the cod are placed in fresh water they sink and never rise again, but are killed—just as a newly-hatched salmon is killed, though somewhat more slowly, by immersion in sea-water. He thinks that even a fall of rain might affect the floating ova in the sea, but this is unlikely.

More than once the eggs of the haddock and other fishes have been brought under notice as lying on the bottom of a vessel, and therefore held as proving that the ova did not float; but in every case such eggs were found to be dead, dying, unripe, or unfertilized. If, in removing the eggs from a fish, too much pressure is applied, unripe eggs escape. Such either sink or float ambiguously, according to the stage of development. Unless this fact is borne in mind disappointment naturally occurs, especially to one who has triumphantly carried such eggs from deep-sea fishing to vindicate statements that have been impugned. No one ever asserted that dead eggs floated. It is the ripe and living eggs that are so buoyant.

In the marine laboratory it has happened that some living ova of the cod rolled on the bottom of the vessel, but this was clearly due to the attachment of fine particles of mud and sand which had gained admission from imperfections in the temporary apparatus, and which surely and speedily in every case proved fatal to the embryo.

The ova and embryos brought from the surface of the sea are comparatively hardy, even though kept for ten days without renewal of the sea-water. The lively little cod, about 5^{mm}. in length, with their characteristic black pigment-patches, swam actively at the surface of the water, darting hither and thither when interfered with, while a stratum of the dead lay at the bottom. The water may even be somewhat milky and the odor characteristic, and yet the embryos survive until, as Professor Sars also found, the yelk-sac, which supplies them with nourishment, is absorbed.

The difference between the larval cod and the young salmon just hatched is striking. The former is in a very rudimentary condition, not only in size, but in structure. For instance, the heart pulsates, but as my colleague, Professor Pettigrew, observed, there is no visible blood and no blood-vessels. Those, therefore, who say that the heart in animals contracts from the stimulus of its living blood, would here find little support. On the other hand, the newly-hatched salmon has attained considerable complexity of structure, and its blood-vessels are well elaborated.

ST. ANDREW'S, SCOTLAND, *November* 10, 1886.