Studies of the Reproduction and Development of Teleostean Fishes occurring in the neighbourhood of Plymouth.

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With Plates I, II, III, IV, V, VI.

The following is a detailed account of the results of my investigations concerning the breeding and the development, under natural and artificial conditions, of some of the fishes met with at Plymouth. These researches extended over the period from the beginning of August, 1887, to the end of August, 1888. I have given brief preliminary accounts of some of the results in No. II of the 'Journal,' issued in August, 1888. As I mentioned there, the laboratory work was carried on from August to November in a small room hired for the purpose near the fish quay; from November to June, 1888, in a single room in the Laboratory without a constant supply of sea-water; after that time the Laboratory being finished all its appliances were available.

Capros aper.

This fish is abundant off Plymouth in the months of July and August, when it is taken in large numbers by the trawlers, who call it the "cuckoo." At this time it is sexually mature, and evidently approaches the shore for the purpose of spawning.

I obtained and artificially fertilized ova on August 15th, 1887, when on board a trawler which fished on the east side of the Eddystone, and found on my return to shore that the fertilization was successful.

The fertilized ovum of *Capros aper* is of a type which is common to a large number of marine species; it is buoyant, very transparent, and spherical; the perivitelline space is small, the egg-envelope has no markings on the external surface, and there is a single oil-globule which in the normal position of the ovum is at the uppermost pole, *i. e.* the pole opposite to the centre of the blastodisc. But the oil-globule, as is usual in similar ova, is able to move freely at the surface of the vitellus at the early stages of development, that is, until the vitellus is completely enveloped by the blastoderm, and therefore when the ovum is placed on a slide in any position the oil-globule usually rises to the upper pole.

The ovum shown in fig. 1, at the stage when the blastoderm had just begun to spread, measured ·97 by ·98 mm. That shown in fig. 2, when the embryo was fully formed but the tail had not begun to grow out, measured 1·2 mm. in the shortest diameter, 1·5 mm. in the longest. The oil-globule is ·19 mm. in diameter. The ova were measured lying on a slide in sea-water without a cover-glass, the measurements being made by first tracing the outline of the ovum with Zeiss's camera, and then throwing the image of a millimetre scale on the tracing. In the later stage the increase in size is due to an expansion of the egg-envelope, the perivitelline space having increased. But ova of a given species are always, within narrow limits, variable in size.

The development was not carried to a later stage than that shown in fig. 2. At that stage black chromatophores had appeared at the sides of the embryo near the dorsal median line, as black specks.

TRIGLA CUCULUS.

I obtained some ova of this species on April 5th and 6th when on board a trawler south of the Wolf Rock, and also some milt, and thought I had effected artificial fertilization, but when I examined the ova on shore I found the fertilization had not succeeded. Another sample, this time successfully fertilized, was brought in by the Laboratory fisherman on April 28th ; they were taken, together with eggs of the common sole and merry sole (*Pleuronectes microcephalus*), on April 27th, about forty miles north of the Longships Lighthouse. On May 13th the Laboratory fisherman returned from a trip on a trawler to the neighbourhood of the Wolf Rock, bringing one bottle of ova of this species fertilized on May 10th, and a bottle of ova of *Trigla gurnardus* fertilized on May 11th. A few more ova of *Trigla cuculus* I fertilized myself at the same locality on May 16th. The natural conditions to which these ova are exposed during development are thus the same as in the case of those of *Pleuronectes microcephalus* (see below), the period of spawning being the same for both species. *Trigla gurnardus* spawns also at the same time.

With regard to the experimental conditions I had not time to pay so much attention to this as to other species. My observations are as follows :—The ova fertilized on April 27th were placed on the following day in a glass jar provided with a constant circulation of water, the jar having a layer of gravel at the bottom in which the lower end of a glass cylinder rested, the outflow passing through a siphon which took the water from the inside of this cylinder. The water supplied on this day was taken near the shore on the flood tide three hours before high water, and had a density of 1·025. The ova sank in this. On April 30th I procured some buckets of water from near the mouth of the Sound, at the Duke Rock, and this had a density of 1·026. As it replaced the other water in the circulation jar the ova rose to the surface. The specific gravity of the ova of this species is therefore about 1·0255. The temperature was 9·2° to 8·0° on May 1st, 8·9° on May 2nd, in the water passing through the jar. On May 4th the water brought in had a density of 1·024, and on account of small tides and continuous rain I could not get water any denser. The ova consequently sank to the bottom, and by May 7th all of them were dead. This case seems to show conclusively that death was due solely to the too low density of the water used. The circulation was nearly constant, and therefore the ova must have been sufficiently supplied with oxygen ; and the temperature was very little higher than that of the open sea. However, the ova lived nine days. Of the ova brought in on May 13th, I placed the *T. gurnardus* in an apparatus like that described above, and left the *T. cuculus* in a jar of still water taken from the shore, having added common salt to it to cause the ova to float. On May 15th I went to sea on board the trawler "Lola." After my return, on May 19th, I found a single newly-hatched larva of *T. cuculus* in the jar, the rest of the ova being dead. This is somewhat surprising, namely, that an egg should live six days and finally hatch, in a small quantity of unchanged water to which common salt had been added. The temperatures of course had not been noted.

Development and structure.—I have given a figure of the ovum of *Trigla gurnardus* to show the early stage, not having drawn one of *T. cuculus* till the stage shown in fig. 4. The dimensions of the ovum in the two species are exactly the same ; the diameter of the ovum is 1·45 mm., of the oil-glouble ·3 mm. There is but a single large oil-globule, which is as usual movable (see under Scomber) in the early stages. The stage shown in fig. 4 in *T. cuculus* was reached in five days three hours. Chromatophores of two colours were present at this stage, some black, the others orange ; both kinds are present on the sides of the embryo, only the orange on the yolk-sac. The characters of the larva are shown in fig. 5, but the figure is not coloured. The black dendritic chromatophores are here as usual specially developed along the edges of the median fin-fold, and both kinds are abundant on the surface of the yolk. The notochord is multicolumnar, and the anus immediately behind the yolk. But the most peculiar feature in the larva is the great size of the rudiment of the pectoral fin. As usual the mouth is not open, but there is an opercular opening leading to the gill-slits. The larva was 3·7 mm. in length.

PLEURONECTES MICROCEPHALUS.

I first got the eggs of this species, along with those of the sole and others, on March 5th and 6th, 1888, when I was on board a trawler which was fishing to the south of the Wolf Rock, which lies to the west of the Lizard Point in Cornwall. In the spring and summer, with few exceptions, all the Plymouth trawlers are accustomed to fish in that neighbourhood. They usually leave the port of Plymouth on Monday morning, about 8 a.m., and as a rule it takes about twenty hours to sail to the fishing ground, which is usually spoken of by the fishermen as Mount's Bay, although the fishing actually takes place some distance to seaward of any limit which could reasonably be defined for that bay. Several times I went on board one of the trawlers named the "Lola," and collected eggs of all the species of fish which were in a ripe condition amongst those brought on deck during the week's fishing. Each boat usually returns to Plymouth on Saturday, and starts again the following Monday.

My first trip lasted only from March 5th to March 8th, as we were obliged to return to Plymouth before the end of the week on account of bad weather. On that occasion I found one or two specimens of *Pl. microcephalus* which were partially ripe, and got a few ova and a little milt; but when I examined these ova afterwards on shore I found they were either dead, or still living and floating, but unfertilized. My next trip lasted from April 3rd to April 7th, when I again got some eggs of the same species, and found on my return that they were not fertilized. On April 11th the fisherman engaged for the collecting work of the Association was sent by me to go out in a trawler fishing on the Plymouth ground, and try to procure some fertilized ova. He returned on April 13th, bringing ova of *Pl. microcephalus* but of no other species. These ova I found were fertilized; they were taken four or five miles south of the Eddystone, the trawl being towed east and west. The Laboratory fisherman went out again in a trawler on April 23rd, the boat fished in the Irish Sea about forty miles north of the Longships Lighthouse. He brought back on April 28th ova of *Pl. microcephalus*, and some other species, but those of the former were unfertilized. He went out again on May 8th, this time on board the "Lola," to the Mount's Bay ground, and returned on May 13th, bringing some fertilized ova of this species. I did not stay on shore to study these, as I was anxious to go out myself to procure soles' ova, and went to sea on May 15th for this purpose. On this occasion I did not get ova of *Pl. microcephalus.* On May 26th some healthy fertilized ova of this species were sent up by the captain of the "Lola;" they were taken near the Wolf Rock on May 24th. The Laboratory fisherman, William Roach, obtained more ova of the same species on May 29th on a trawler to the south of the Eddystone, and this was the last lot that I received.

It thus appears that the species we are considering spawns during April and May, the period, no doubt, extending in the case of a few individuals slightly beyond these limits in either direction.

A few data were obtained to indicate the physical conditions to which the ova are normally exposed. The density of the water in the neighbourhood of the Eddystone is 1·0267 to 1·0269 (see under Scomber).

On April 7th I brought a clean sample of sea-water from where we had been fishing, south of the Wolf Rock, in a stoppered bottle, and found its density when tested in the Laboratory was 1·0270. The temperatures observed were as follows:

April 4th.—South-east of Wolf Rock	Surface	7·5° C.
„ 12th.—5 miles south of Eddystone	Surface	7·2° C.
	Bottom, 40 fms.	6·6° C.
„ 16th.—Ditto	Surface	7·5° C.
„ 25th.—40 miles north of Longships Lighthouse	Surface	7·7° C.
	Bottom, 50 fms.	7·2° C.
May 10th.—10 miles south-east of Wolf Rock	Surface	10·0° C.
	Bottom, 45 fms.	8·9° C.
„ 29th.—6 miles south-west of Eddystone	Surface	9·4° C.
	Bottom, 40 fms.	8·8° C.

In describing the artificial conditions under which the ova were kept in the Laboratory, I shall consider first and more fully those obtained on April 12th about five miles south of the Eddystone, as from these all the figures and most of the description given below of the development were taken.

When these ova were brought in I transferred them to some water taken a short distance from the shore opposite the Laboratory; the density of this was 1·026, and the ova all floated in it without difficulty, remaining in a layer at the very surface. They were simply left in jars of the water, with no arrangement for continuous aeration or circulation, but were transferred to clean water every day. On April 14th the temperature of the water in the jars was 12·5° C., more than 5° higher than the surface temperature of the open sea where they were taken. The subsequent temperatures in the jars were: 16th, 11·6° C.; 17th, 13·0° C.; 19th, 11·8° C.

A large proportion of this lot of ova hatched, and some of the larvæ lived five days after hatching. The larvæ after hatching were placed in a jar with gravel at the bottom, supplied with a constant inflow of water, the outflow taking place from a cylinder whose base was inserted in the gravel.

On the 18th I found that water brought up from the shore had a density of 1·023, and in this ova of *Pl. microcephalus* rapidly sank.

The ova fertilized on May 24th were also left in still water, having a density of 1·026, and a temperature on the second day of 13·7° C. These hatched on May 30th. Another lot, fertilized on May 29th, were placed in a Chester apparatus (see under Scomber), made with a square wooden washing tray, and provided with a nearly constant supply of water from the shore. (All this time I was restricted to a single room, all water being carried up by hand.) The temperature of the water was 12·4° C. These ova were all dead on May 31st, the fatality being probably due to the impurity of the apparatus; the washing tray was fastened with white lead, and washed muslin was used over the bottom of the jars containing the ova.

It is thus shown that the ova of *Pl. microcephalus* are extremely hardy, and can be hatched without any difficulty in still water whose temperature and density differs considerably from those to which the ova are exposed under normal conditions. The next step is to make arrangements for collecting and hatching these ova on a large scale, and transferring the hatched young to the sea, in order to find if the supply of merry soles is thereby increased.

The specific gravity of the ovum of *Pl. microcephalus* is about 1·024; they floated in water having a density of 1·025, and sank in that of density of 1·023.

Structure and development.—The ovum of *Pleuronectes microcephalus* resembles that of other species of the same genus, and of many species of Gadus (cod, haddock, whiting, &c.) in having a perfectly homogeneous yolk without oil-globules, and a small perivitelline space. Its diameter is usually 1·36 to 1·44 mm., though individual ova may be a little smaller or a little larger than this. The external surface of the vitelline membrane (egg envelope) is not perfectly smooth, but shows a number of fine raised ridges forming two systems of parallel lines, which cross one another diagonally. Fig. 6 shows the appearance of the ovum under the microscope when the blastoderm has almost entirely enveloped the yolk. In the ova fertilized on April 12th, at 1 p.m., and kept under the conditions already detailed, segmentation was completed on the first day, and on the second the extension of the blastoderm over the yolk took place. On the third day the differentiation of the optic vesicles and of the mesoblastic somites commenced. On the fourth day the lens and auditory vesicles were formed, and the first development of pigment appeared as black dots on the sides of the embryo. Fig. 7 shows the condition on the fifth day: the intestinal tube is formed, the notochord is present and already shows the multicolumnar arrangement of its vacuoles, and the cavity of the heart has appeared as a simple slit in the mesoblast below the neck. The black chromatophores are but little further developed. A number of the larvæ hatched out on April 19th at the end of the seventh and commencement of the eighth day after fertilization. The structure of the larva is shown in fig. 8. It is 3·8 mm. in length. There are now yellow chromatophores as well as black, and both are dendritic. They are present in the median fin-fold, on the sides of the body, and on the surface of the yolk, where they are situated at the surface of the periblast. The mouth is not open, the nasal pit is seen at the anterior end of the head, the heart is more developed and contracts regularly, but there are no red corpuscles. The anus is open and situated immediately behind the yolk. There is a large cavity (the venous sinus) in front of the yolk, between it and the anterior abdominal wall. The notochord is not altered. Besides the median fin-fold there are rudiments of the pectoral fins in the form of a semicircular fold of membrane on each side behind the auditory vesicle. The cavity of the intestine is plainly visible. The larva four days after hatching (fig. 9) is considerably more developed. The mouth is not opened, but its cavity is large and only separated from the exterior by a thin membrane, and three or four gill-slits are open leading from the pharynx to the exterior. The yolk is almost absorbed, and the abdominal region therefore does not protude so much. The venous sinus is still large and its communication with the posterior end of the heart is plainly seen. Red corpuscles are still absent, but white corpuscles or leucocytes are to be seen moving in the venous sinus and passing into the heart. In front of the remnant of the yolk is seen the liver, as a bulbous follicular outgrowth from the wall of the intestine. The urinary bladder is visible behind the rectum. The head is much shortened, so that the auditory vesicle is much nearer to the eye. The pectoral fin is considerably developed, but no fin rays are present in it. The pigment is much more abundant, and has a definite arrangement. The yellow pigment is confined to the body of the larva and the surface of the yolk; on the former it is abundant, especially about the head. The black chromatophores form a fringe at the edges of the median fin, and others are also present on the body and the yolk-sac. The larva is still perfectly symmetrical; no indication of the asymmetry of the eyes and skull is yet apparent. The larva at this stage has a total length of 4·6 mm.

SOLEA VULGARIS.

Observing that the ovaries of soles brought in by the fishermen were approaching maturity, I went out in a trawler on February 6th, 1888, to obtain, and to artificially fertilize, some ripe ova. On this occasion, as on many others when I was similarly engaged, the trawl was brought on deck after darkness had set in, and I had to carry on operations by the dim light of a lantern. From one specimen I got a few ova, but could get no milt. The ova, when examined on shore next day, were found to be unfertilized, though two or three were floating. On this occasion the boat, when the trawl was hauled, was about nine miles west by south of the Eddystone.

My next attempt was on March 6th, when I was on board the "Lola," south-east of the Wolf Rock. At one haul of the trawl I got, out of about thirty-five soles, two or three which yielded a few ripe ova on squeezing, but I could obtain no milt from any of them. On opening those which I judged to be males I found small testes in the usual position, and these I cut out and divided into small pieces, and placed these in the water with the ova, hoping that sufficient spermatozoa for fertilization would thus be obtained. This difficulty in obtaining the milt of the sole, an unexpected obstacle to the investigation of the development of the species, occurred constantly on every subsequent occasion when I tried to obtain fertilized ova. The cause of it I have not yet discovered. There is no such difficulty in the case of other flat-fishes; the ova of the merry sole were fertilized with ease, sufficient milt could almost always be obtained by squeezing males, and at other times I have fertilized the ova of *P. flesus* (the flounder), *P. limanda* (the dab), *P. cynoglossus* (the witch, or pole flounder); but I was not able during the whole of last season ever to squeeze any milt out of a male sole. The probable reason is that the testes of the sole are extremely small.

On March 7th I examined the soles of another haul with the same result. On my return to Plymouth on March 8th I found only about a dozen of the ova floating, and of these only two or three showed a blastoderm, that is, were fertilized. Thus the pieces of the testes placed in the water had effected fertilization only in a few ova of the whole number. The few I had were used up for microscopic examination.

In my next trip to Mount's Bay on April 3rd to 7th, I took some sole's ova as before, using entire testes cut into pieces to fertilize the ova. But on my return I found that this time not a single ovum was fertilized. At this time only a few soles were taken at a haul on the Plymouth ground, and it was necessary to go to Mount's Bay in order to have a chance of getting ripe specimens at all. But after this nearly all the trawlers went round the Land's End and fished on the north coast of Cornwall, so that it was difficult to arrange a trip unless one was prepared to stay out a fortnight, which would have made it impossible to get any results from the material obtained. I sent the Laboratory fisherman on one of these long trips, April 23rd to 28th, but the sole's ova he brought back were unfertilized. He went again to Mount's Bay, May 8th to 13th, and was again unsuccessful. I went myself May 15th to 18th, when I found a good many of the female soles spent, but again failed to get milt; I employed the testes as before, and on my return on May 19th I found a few of the ova fertilized.

The common sole thus spawns in March, April, and May. The temperatures of the open sea during the last two months are given under *Pleuronectes microcephalus.* Off the Wolf Rock on March 6th the temperatures were: surface 7·7° C., thirty fathoms 7·5° C. I found that sole's ova sank in water of 1·026 specific gravity and floated at 1·027, so that their specific gravity is between these numbers.

Structure and development.—The ovum of *Solea vulgaris,* after extrusion and fertilization, is of considerable, size; of two that I measured one was 1·47 the other 1·51 mm. in diameter. It is distinguished from the greater number of the pelagic ova of other genera by two peculiar characters, both connected with the yolk. One is that instead of having a single large oil-globule, or a small number of these, it has an immense number of very minute size. These are arranged in groups of irregular shape, the globules of a given group being all in contact with one another. At the early stages most of these groups are near the edge of the blastoderm, but without any constant arrangement (fig. 10). The other character is that the yolk is not perfectly continuous and homogeneous, but co-extensive with the blastoderm there is a single superficial layer of separate yolk-masses, or yolk-segments, having a somewhat rounded outline, but not spherical (*y. s.* in figs. 10, 11, &c.) This layer of yolk-segments extends with the blastoderm, so that when the latter has enveloped the yolk the layer of yolk-segments also envelops it completely, forming a superficial layer over the whole surface of the yolk as seen in fig. 11. When the embryonic rudiment becomes distinct, and especially after the yolk is completely covered by the blastoderm, the groups of oil-globules are mostly aggregated on each side of the embryo, though there are a few groups at other parts of the surface of the yolk (fig. 11).

I have only, on account of the great scarcity of my material, been able to examine two stages in development from artificially fertilized eggs. Fig. 10 shows a living but unfertilized ovum, drawn on March 8th. The development of a fertilized ovum examined on the same day had evidently been very slow, owing to the low temperature to which it had been exposed; the temperature of the surface sea-water in which the ovum was fertilized was 7·7° C., and as the jar had been kept on board the trawler until shortly before the time when the ovum was examined, the temperature of the water containing the ovum was probably even lower than this during the two days.

Fig. 11 is taken from another ovum fertilized on May 16th, and drawn three days afterwards, the temperature at fertilization having been about 10° C., and in the jar containing the ovum during the time it was on board the boat probably somewhat higher. At this stage the enclosure of the yolk by the blastoderm has been completed, the embryo is distinctly formed, the optic vesicle is present, and the vesicle at the posterior end, known as Kupffer's vesicle, is fully developed; this vesicle is unusually large. Black chromatophores have appeared on the sides of the embryo and on the surface of the yolk, the former being still in the form of dots, the latter dendritic or stellate in shape.

It is evident that the peculiarities of the sole's egg enable it to be easily recognised when taken in the open sea in the tow-net. Twice I obtained specimens in this way. The first time was on March 16th, 1888, from a tow-net worked between the Tinker and the Knap buoys just outside Plymouth Breakwater, just after high water, when the temperature at the surface of the water was 6·6° C. There were three ova altogether, one of which is shown in fig. 12. The diameter of this was 1·47 mm. The individual oil-globules and the vitelline segments were of somewhat larger size than in the artificially fertilized ova, but this is probably a mere individual variation, and there can be little doubt that the ova belonged to *Solea vulgaris*.

The second time was on April 18th from a tow-net worked on the east side of the Sound, when I found only a single ovum, which is figured in fig. 13. This ovum was in the same stage as the artificially fertilized one shown in fig. 11, but it is figured in a different position. It agrees in structure exactly with the ova taken directly from the parent fish, but its apparent size in the figure is greater. It was drawn under a cover-glass, and in this condition measured

1·67 mm. in diameter, the difference being due partly to the flattening caused by the pressure of the cover-glass, and partly perhaps, to individual variation, as the eggs of a given species always vary in size within certain limits. The position of the groups of oil-globules at the sides of and beneath the embryo is clearly shown in this figure.

Historical and comparative.—Imperfect as is the foregoing account of the ova of *Solea vulgaris* and their development, it is the first definite information yet afforded concerning the eggs of this species. Certain facts concerning the structure of the ova in the genus Solea have been published by Dott. Fed. Raffaele in a paper on the eggs and larvæ of Teleostean fishes in the Gulf of Naples,* which appeared in March, 1888; but Raffaele has only described fertilized developing ova obtained by the tow-net from the surface of the sea, and did not identify any of these ova with a definite species. He ascertained the peculiarities of the ova in the genus by examining mature ovaries of *Solea impar, vulgaris,* and *Kleinii,* and says that these peculiarities, although distinguishing the ova of Solea from any other pelagic ova, render the ova of the different species so similar that they cannot, when obtained at random (*i. e.* from the open sea) be distinguished easily from one another. These peculiarities are those I have described, namely, the groups of minute oil-globules, and the superficial layer of yolk-segments, which Raffaele calls "vescicole vitelline," speaking of the whole layer as the "zona esterna vescicolare."

Raffaele describes two kinds of ova of Solea obtained by the tow-net, and not having been able to determine their species, he calls them Species A and Species B. Species A was 1·06 mm. in diameter, and was obtained in January. He gives two figures of this ovum, which are both indistinct, and also six figures of the larva at different stages, which are much better. Species B was larger, 1·23 mm. in diameter; of this he gives no figures of the ovum, but three figures of the larva. Neither of these species probably belonged to *Solea vulgaris,* as the largest of them is ·2 mm. smaller than the ovum of the latter according to my measurements.

Raffaele notices the change in the relative position of the groups of oil-globules as the blastoderm grows over the yolk, attributing it to the fact that they are situated in the cortical protoplasm which divides the vitelline segments, and therefore take part in the movement of the latter. I cannot say whether the oil-globules in the sole's ovum are freely movable at first like the single globule in Scomber, Trigla, &c.

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* *Le Uova gallegianti e le Larve dei Teleostei nel golfo di Napoli,* **Mittheilungen aus der zoologischen Station zu Neapel, Bd. viii, Heft 1.**

The layer of separate vitelline segments is not exclusively confined to the ova of Solea; it is the combination of this character with the peculiar arrangement of the oil-globules which distinguishes this genus. The external segmental layer of the yolk was first noticed by Agassiz and Whitman* in a species of ovum which they ascribe to *Temnodon saltator,* Linn., known in America as the blue-fish. Temnodon belongs to the same family as the boar-fish, *Capros aper,* whose ova have been described above, namely, the Carangidæ. Agassiz and Whitman state that when the blastoderm has enveloped the yolk the yolk-segments are absent immediately beneath the embryo, but I have not verified this in Solea. In the ova described by these authors there is but a single oil-globule of considerable size, and judging from the figures which show the globule in different positions it is mobile at the early stages.

Raffaele describes a perfectly similar superficial layer of segmented yolk in *Mullus surmuletus,* L., the red mullet. He informs us, moreover, that in the ovarian ovum of Mullus when it is approaching maturity the yolk-segments are in the centre of the ovum, and are nothing but a portion of the vitelline segments which at an earlier stage make up the whole mass of the yolk. Most of these segments fuse together to make up the homogeneous part of the yolk; the remainder pass to the surface and take up a position beneath the germ or blastodisc, persisting during development. The partitions enclosing the segments Raffaele believes to be protoplasmic and continuous with the protoplasm of the germ, by which he explains the fact that the yolk-segments are involved in the movement of the blastoderm. The explanation is in all probability correct.

The superficial layer of segments is also described by Raffaele in the ovum of *Callionymus festivus,* and in an unidentified ovum (Species No. 2 in his paper) with a diameter of ·75 mm. which he says resembles that of Callionymus. He states that in *C. festivus* the layer of segmented yolk extends all round the ovum from the beginning, even in the mature ovum before fertilization, and undergoes no movement during the extension of the blastoderm. He refers to a description by McIntosh of the ovum of *C. lyra* (Ann. Mag. Nat. Hist., vol. xvi, 1885), in which it is stated that the surface of the vitelline membrane in this species exhibits a hexagonal mosaic of raised lines, and says that nothing of the kind being visible in the ovum of *C. festivus,* McIntosh probably saw the follicular epithelium attached to the ovum when it was taken from the ovary, and mistook this for a marking of the vitelline membrane.

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* *Pelagic Stages of Young Fishes,* Memoirs of Museum of Comp. Zoology, vol. xiv, No. 1, pt. i, Cambridge, 1885.

But I am able to confirm entirely McIntosh's statement with regard to *C. lyra*. I examined ripe ova squeezed from a mature female, and saw the hexagonal reticulum figured by McIntosh, and further, I took in the tow-net in the Firth of Clyde in 1886 an ovum well advanced in development, which showed exactly the same marking, and which agreed in all characters with the ripe ovum of *C. lyra*. Moreover, I saw no layer of yolk-segments in this species. At Plymouth I again met with the same ovum on February 1st, 1888, inside the Sound; two views of it are shown in figs. 26 and 27; the former shows an optical section, the latter the surface of the vitelline membrane. This ovum measured in one case ·90 mm., in another ·97 mm. Raffaele gives as the diameter of the ovum of *C. festivus* ·56 to ·60 mm. The Italian author speaks as if he had taken the ova directly from the parent fish, and thus it would seem that there are great differences between the ova of these two species of the same genus, but they agree in having no oil-globules.

The other kind of ovum with a peripheral layer of yolk-segments is briefly described by Raffaele (No. 2 of his undentified species). This has a diameter of ·75 mm., and has a number of rather large oil-globules scattered separately over the yolk; it was obtained by the tow-net in January.

As it seems not quite certain that the identification of the ovum of Temnodon by Agassiz and Whitman is correct, and there is some doubt about *Callionymus festivus* and the other species, Mullus and Solea are left as the only genera whose ova undoubtedly have the peripheral layer of yolk-segments. It is interesting to notice that these ova present a condition of the yolk intermediate between that characteristic of non-pelagic ova and that seen in typical pelagic ova. Oil-globules occur equally, either singly or in numbers, in both kinds of ova, but in all adhesive ova the yolk is made up of a number of minute yolk-spheres, and in nearly all pelagic ova the yolk is one mass, continuous and homogeneous, a single yolk-sphere. The adhesive ova are characteristic of nearly all shore fishes from the large Cyclopterus to the minute Goby, and also of the greater number of Physostomi, *i. e.* of the more primitive fishes with an opening to the air-bladder. But certain Clupeoids, *e. g.* the pilchard, although belonging to the Physostomi, have pelagic ova, and in these ova the subdivision of the yolk is retained at all stages; then in Solea and Mullus the central part of the yolk is fused into one mass, while a peripheral layer continues segmented; and finally in most pelagic ova the segments disappear altogether, and there is no subdivision of the yolk at all. It is possible that the peculiar character of the ovum of Solea indicates that there is no close affinity between this genus and Pleuronectes; the adaptation to the habit of lying on one side may have brought about a superficial similarity in fishes originally derived from distinct families. I hope to decide this question by a careful comparison between soles and other kinds of flat-fish in all points of adult structure.

SOLEA VARIEGATA.

I did not devote much attention to this species, as my time was occupied with others; the following notes are therefore very meagre. Until May 30th I had not been able to find any of this species in a ripe condition. On that day the Laboratory fisherman brought me a few ripe ova which he had taken from a fish on board a trawler six miles south-east of the Eddystone. He had not been able to get any milt. When I examined the ova they were all at the bottom of the jar apparently dead, and all I could make out was the size and a large group of numerous oil-globules, individually larger than those of *Solea vulgaris*. These all collected at the highest point of the ovum when placed on a slide. The diameter was 1·36 mm. The appearance of the ovum is shown in fig. 14.

On July 17th, I obtained from a tow-net worked by the Laboratory fisherman from a mackerel boat south-east of the Eddystone a peculiar kind of pelagic ovum which is shown in fig. 15. This had a superficial layer of yolk-segments, like *Solea vulgaris*, but the oil-globules, though rather numerous, were of rather large size, and were scattered singly at nearly equal distances over the surface of the yolk. The diameter measured 1·36 mm. Thus the size of the ovum and of the individual oil-globules agreed closely with the dimensions noticed in the unfertilized ovum of *Solea variegata*. I conclude provisionally that the ovum shown in fig. 15 belongs to this species. Raffaele examined the ovarian eggs of only three species, *S. impar, vulgaris* and *Kleinii*. Impar is considered by Day in his Fishes of Great Britain and Ireland as synonymous with lascaris, which is Couch's lemon sole, and occurs occasionally on the coast of Devonshire; Kleinii occurs only in the Mediterranean. Thus there is nothing to show that *Solea variegata* may not have separate oil-globules; and although in the dead unfertilized ovum I observed them all in one group, this does not prove that they are not in the later stages of the living egg fixed at a distance from one another. Moreover, Raffaele describes and figures among his undetermined species an ovum which agrees in all respects with that shown in fig. 15 except that it is 1·4 mm. in diameter instead of 1·36. This difference may be due to the conditions of measurement or to individual variation. Raffaele thinks his ovum belongs to another species of Solea; it seems to me probable that it belongs to *Solea variegata.*

Other species of Pleuronectidæ.—It will be useful here to summarise the present state of our knowledge concerning the reproduction of other species of the flat-fish family. I have already mentioned that Day considers *Solea lascaris* and *Solea impar* of Günther's British Museum Catalogue to be one and the same species, and that Raffaele has examined the mature unfertilized ovum and finds it has the same peculiarities of structure as *Solea vulgaris.* The species occurs occasionally at Plymouth, but I have never met with a specimen, and it is too rare to be of any importance for practical hatching. Day also unites *Solea lutea* and *Solea minuta* of Günther. This is a very small and practically unimportant species which also is rare at Plymouth, and I have not seen a specimen.

Of Pleuronectes I have previously* described the ova and development of *P. flesus,* the flounder; *P. limanda,* the dab; *P. platessa,* the plaice, and *P. cynoglossus,* the witch, or pole flounder. These, with *P. microcephalus,* are the only British species of the genus. The eggs and larvæ of all these species are closely similar and differ only in size. The eggs and larva of *P. Americanus* described by Agassiz and Whitman in Pelagic Stages, &c., have the same characters.

Rhombus maximus, the turbot, and *R. lævis,* the brill, both occur at Plymouth. I have not been able to get ripe ova of either, but Raffaele considers certain ova which he obtained from the tow-net, which had a diameter of 1·33 mm., a homogeneous yolk, and a single large oil-globule, as belonging to *R. lævis.* He also figures larvæ of this species. Wenckebach describes the mature ova of *R. maximus* as having a diameter of ·75 mm.

Arnoglossus includes two species which occur at Plymouth, of which *Arnoglossus laterna,* the small scald-fish, is of no importance in the fish market. Concerning this species I have some incidental remarks to make. It is very common at Plymouth, and inside the Sound, especially in Cawsand Bay, young specimens of all sizes from three quarters of an inch long up to the full size of about six inches, are taken in numbers by the small trawls used for catching shrimps. It is constantly reported by fishermen that the shrimpers catch numbers of young soles, but the report is simply founded on a mistake, these young scald-fish being erroneously taken for soles. On August 15th, 1888, I went, with Mr. Bourne, on purpose to test this matter, and after trawling for a long time in Cawsand Bay we got large numbers of young scald-fish, but only one young specimen

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* *The Eggs and Larvæ of Teleosteans,* Trans. Roy. Soc. Edinb., vol. xxxiii, pt. 1, 1887.

of *Solea vulgaris.* In one point the descriptions and figures of *Arnoglossus laterna* given by Day in his British Fishes, and by Günther in his Catalogue of the British Museum Collection are a little too vague. The latter author does not of course give a figure for each species, and he speaks of the anterior curve of the lateral line in this species is subsemicircular. The former describes it as almost semicircular, and figures it as a rounded curve much like that of Zeugopterus. The anterior part of the lateral line in reality forms almost three sides of a square, and has another smaller curve still farther forwards, as shown in outline in fig. 39.

Raffaele states that the mature ova of Arnoglossus are ·60 to ·70 mm. in diameter, with a homogeneous yolk and a single oil-globule, and cannot be distinguished from those of Rhomboidichthys and Citharus, genera of Pleuronectids occurring in the Mediterranean, but not in Britain. It would seem therefore that the ova of Arnoglossus only differ from those of Rhombus in size.

Two species of Zeugopterus occur at Plymouth. I have met with a specimen of *Z. punctatus* taken in a lobster pot. They have no value in the market and their ova are not known.

SCOMBER (the Mackerel).

My first examination of living mackerel was made on board a boat called the "Prima Donna," on May 24th, 1888. On this occasion the nets were shot on the east side of the Eddystone, about fourteen miles from Plymouth Sound; and when they were hauled at daybreak in their whole length of nearly two and a half miles only abont fifty mackerel were taken. Several of these were males in a perfectly ripe condition, but only one ripe female was found, from which a number of ova were taken and fertilized. The skipper and the men having seen performed the simple operations necessary to obtain and fertilize the eggs, I left a basket of collecting bottles on board, and they supplied me with fertilized ova almost every time they went to sea. In fact, by this skipper and another, who was also taught how to collect them, more ova were sent to me than I could deal with, and I had to tell them not to send any until I gave them notice. The spawning continued from the end of May till the middle of July, and throughout this time I was studying and making experiments with mackerel ova. I received the last of the season on July 17th. It follows from this that mackerel in the neighbourhood of Plymouth spawn principally in June and the first half of July, that the ovaries and testes of all the adult fish become ripe within this period, and that all the reproductive products in a given fish are matured and shed within a short space of time. The process of spawning, that is to say, as usual in species of fish that swim in shoals and have migratory pelagic habits, is approximately simultaneous in all the specimens in a given locality, proceeds very rapidly when once begun, and is limited definitely to one short period of the year.

Physical conditions during development.—I have collected a few data concerning the density and temperature of the water at the surface of the sea, some miles from the Sound, that is where mackerel ova are shed under natural conditions.

March 23, 1888.—Water brought in from 2 miles outside the breakwater	Density	1·0268
	Temp. when tested	8·2° C.
April 7.—Water from 7 miles south of Wolf Rock	Density	1·027
	Temp. when tested	7·5° C.
June 1.—Water in which mackerel ova were floating when brought in; that is, water taken from the surface at the place where the mackerel were caught.	Density	1·0267
June 2.—Water in which mackerel ova were brought in from sea.	Density	1·0268
July 17.—Ditto	Density	1·0269
	Temp. when tested	15·0° C.
May 31st.—Temperature of the sea 2 miles outside the breakwater.	Surface	9·44° C.
	Bottom, 12 fms.	10·0° C.
June 12.—Temperature of sea at 7 miles south-west of the Eddystone, taken with Casella's reversing thermometer in the "Scottish" frame.	Surface	11·6° C.
	Bottom, 40 fms.	10·0° C.
July 10th.—Temperature of sea in middle of Plymouth Sound, Melampus Buoy.	Surface	13·3° C.
	Bottom, 7½ fms.	12·7° C.

With regard to the temperature of the sea at places where spawning mackerel were caught, that is in the neighbourhood of the Eddystone, it is certain that it could not have been higher than the temperature in the Sound and a short distance south of the breakwater. This temperature therefore between June 12th and July 10th rose from the temperature observed at the mackerel ground on the former date, namely, 11·6° C., to something less than that observed in the Sound on July 10th, namely, 13·3° C. With regard to density, the specific gravity of water from the mackerel ground was ascertained on shore three times, and was 1·0267 on June 1st, 1·0268 on June 2nd, and 1·0269 on July 17th. The temperature of the sample at the time when the density was observed was only once ascertained, on July 17th, when it was 15·0° C. The temperature of a small quantity of water in a bottle carried on a fishing boat, and examined in the Laboratory in June and July, must of course be somewhat higher than its temperature when taken from the sea, but we see that the greatest difference of temperature between the sea and the observed sample of sea-water was that between 11·6° C. and 15·0° C., or 3·4°. Thus the density of the water at the surface of the sea was slightly greater than that observed in the samples, allowing for the expansion of the water caused by a rise of temperature of two or three degrees. But this difference of density would be scarcely appreciable, and we may therefore conclude with certainty that the density of the surface water of the sea was not less than 1·0267 and very little higher than 1·0269. The temperature on June 12th, seven miles south-west of the Eddystone, was 11·6° C., and on July 10th less than 13·3° C.

The following data of the conditions of temperature and density to which the ova were exposed during the Laboratory observations are to be compared with the natural conditions ascertained above. The first lot of ova I got, namely, those taken on May 24th, I placed in a glass jar of water provided with a slow circulation; at the bottom of the jar was a layer of gravel, and a glass cylinder with its base in the gravel surrounded the siphon through which the outflow took place. Thus the ova were prevented from approaching the exit siphon, while the water passed through the gravel up into the inside of the cylinder. This apparatus was arranged at 10 a.m. on May 24th, and on the following day I found that all the ova had sunk to the bottom of the jar, and were in a dead or dying condition. A few of the ova which had been left in the water brought in from the sea were still alive and developing. The water supplied to the circulation apparatus was brought up from the shore, as at this time I was restricted to my single room in the Laboratory, and the aquarium apparatus was not built. The result showed that the water from the shore, although constantly supplied in a pure condition to the eggs in the circulation apparatus, was rapidly fatal, while in the water from the open sea, although perfectly still and unchanged, the ova lived.

On May 26th more ova were sent up by the crew of the "Prima Donna." I had some clean water brought up from the shore, and found that its density was 1·0260, and its temperature 13·7° C. In this water the mackerel ova slowly sank, although the ova of *Pleuronectes microcephalus*, which I had at the same time, rose to the surface in it as soon as they were introduced. It is remarkable that there should be so considerable a difference in the specific gravity of the ova of the two species, the more so as the mackerel ovum has a large oil-globule, and the merry sole none, and yet the former is a good deal the heavier. As these mackerel ova were in perfectly clean water when brought in I did not transfer them to the water from the shore, but only added a little of the latter to the water containing them, taking care not to decrease the density so much as to cause them to sink. I discarded the circulation method this time, and left them in bottles of still water.

On the 27th I was obliged to transfer them to shore water, in which they sank, but I brought them to the surface again by adding common salt. I found on testing I had raised the density to 1030, which was excessive.

On the 28th I found the temperature of the water containing the ova was 12·1° C. I changed them again into clean water made denser with salt. Many of them were still doing well.

On the 29th the water was again changed, and the temperature of the old water was 12° C., of the new 11° C.

On the 30th I fitted up an apparatus on the principle invented by Captain Chester, of the Fish Commission of the U.S.A., and described by A. Ryder in the Commissioner's Report for 1885, p. 499 (Washington, 1887). I procured a wooden washing tray with a hole bored in one side near the top, in which hole, by means of a cork, I fitted a glass siphon with its shorter leg inside the tray. In the tray I placed a glass cylinder open both at the top and the bottom; over the lower opening a piece of muslin was fastened. The eggs were placed in the cylinder, and a supply of water allowed to run at a constant rate into the tray. In consequence the water rose in the tray and the glass cylinder to the height of the hole in the side of the tray when the siphon commenced to act, and the water was drawn off until the level was lowered below the short leg of the siphon, when it commenced to rise again. Clean water in such an apparatus is thus constantly flowing over the eggs, while the latter are only subjected to very gentle motion.

But it would have been better if I had not been tempted to try circulation again. On the 31st a great number of the ova were dead, and by the evening of this day I could find none alive, and they all had to be thrown away. The damage may have been partially or wholly due to impurities derived from the wooden tray or the muslin, but the probable meaning of the result is that density is an essential condition; the ova lived and developed four days in still water in which they floated without motion at the surface, although the water for three of these days was shore water made denser with common salt, and when placed in a current of shore water to which no salt was added they died in twenty-four hours.

In this case the temperatures to which the ova were exposed during the first four days as observed were 13·7° C., 12·1° C., 12° C., and 11° C. The densities were 1·0267 to 1·030. The temperature of the open sea on May 31st was not more than 9·44 C., and the density 1·0267 or a little more. The temperature of the water on the last day in the Chester apparatus was 12·4°, while its density was not greater than 1·0260. Thus the ova were not injured during the first four days by a temperature more than 4° higher than that of the open sea, and a density increased on one occasion by ·0033, but they died on the fifth day in a circulation in which the temperature was the same as before, and the density decreased by ·0007 or somewhat more. Unless the motion or impurities from the apparatus killed them, it must be concluded that they died because they sank in the water.

My next experiment was still more unsuccessful. Ova were brought in on June 1st, and I transferred them to water fetched from near the breakwater; the density of this was 1·0255. I added salt to it till the density was 1·0265. On June 2nd the temperature was 14° C. I then changed the water, and placed half the ova in a glass jar provided with a circulation, the outflow being protected by muslin; but on June 3rd both halves, that in the still water and that in the circulating, were dead.

On June 12th I received a number of healthy fertilized ova from the "Prima Donna," taken seven miles south-west of the Eddystone. I placed these in a Chester apparatus, made with a perfectly clean wooden tub instead of the tray formerly used, and placed them in the tank-room, as the aquarium apparatus was all but complete and the pumps were working. By placing the tub under one of the jets I expected to obtain a constant supply of water to the apparatus, which was impossible in my single room, where each bucket of water had to be carried up by hand. But the pumps had to be stopped and all the ova died.

On June 29th I received a fresh supply, and as the aquarium pumps were now working continuously I kept these in a Chester apparatus on the shelf below the small tanks in the main laboratory, water being supplied to the tub by means of a siphon from the tank above. Some of these ova lived well for some days, but they sank in the water because its density was not great enough. And as some of the ova died the living and dead were all mixed together in a mass lying on the muslin at the bottom of the jar, a condition which was obviously unhealthy. The water in circulation in the aquarium system of the Laboratory varied somewhat in density, because frequently some water had to be run off from one of the large reservoirs to allow some slight defect in the arrangements to be attended to, and then more water was pumped up from the shore to make up the loss. On June 8th the density of the circulating water was 1·0260, on August 15th it was 1·0250; it varied between these two limits. On July 4th the temperature of the water in the tanks in the main laboratory was 14·5° C. The temperature of the open sea at this time was not much above 12° C. Thus, in this last experiment with mackerel ova the temperature was only about 2° higher than that of the open sea, and the density was 1·0250 or 1·0260 instead of 1·0267.

Some of these ova hatched on July 4th, on the sixth day after fertilization, but these were few in number, all the rest being dead; the larvæ were also half dead and had not strength enough to survive more than a few seconds when placed on a slide; consequently I was unable to get a drawing of them. On July 5th there were neither larvæ nor ova left alive. I got another sample of mackerel ova subsequently, but they were only partially fertilized and soon died.

It is difficult to say whether the death of the ova in the experiment conducted from June 29th to July 5th under the most favorable conditions, was partially due to the presence of impurities derived from the new apparatus, but it has generally been observed that in a new aquarium the animals die in considerable numbers notwithstanding all care. It was so to a certain extent in ours,—there were more deaths at first than subsequently; and the fact of the system having been so newly arranged may have had an unfavorable effect on the mackerel ova; but I believe the chief cause of failure was the insufficient density of the water. Apart from the question whether buoyant ova will develop normally in water of such low density that they sink in it, it is certain that in the apparatus used for floating ova the conditions become unfavorable if the ova sink. They are insufficiently supplied with oxygen, and it is impossible to separate the dead ova from the living. Some pelagic ova have been found near or on the bottom in the Baltic, where the density of the water is below that of the open seas. The observations I refer to were made at Kiel by V. Hensen,* a member of the Commission for the Investigation of German Seas, and they refer only to plaice, flounder (*Pleuronectes flesus*), dab (*Pl. limanda*), and cod. By fishing with a fine net attached to a dredge at the bottom, at a depth of nine fathoms, about eighteen miles from Kiel, at the mouth of Kiel Bay, he obtained ova of the three species of Pleuronectes mentioned, and these afterwards hatched in captivity. The specific gravity of the water at the place mentioned has an average for the year of 1·0128, and the maximum observed during several years was 1·0201, and the average temperature in April, when the ova were taken, was 6·11° C. Hensen found that the ova of the plaice, after having been shed into sea-water had a specific gravity of 1·01496;

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* *Ueber das Vorkommen und die Menge der Eier einiger Ostseefische*, 4ter Bericht der Commiss. zur Unters. der deutschen Meere, IIte Abtheil., 1883.

and found that in eleven years, in March three times, in April three times, in May seven times, the maximum specific gravity of the water off Kiel Bay was lower than that of the plaice ovum. Thus in these years the ova of Pleuronectes species would have to develop on or near the bottom. Hensen does not give any details of the apparatus in which he hatched the ova artificially, but I infer from his remarks that he hatched them when they sank in the water of the vessels containing them.

But of course it does not follow that mackerel ova will develop healthily in water of less specific gravity than themselves. And it is certain that it was a constant result in my experiments that mackerel ova floating at the surface in still water, even when the density was artificially increased with common salt, lived some days, while those provided with a circulation of water in which the ova sank died in a much shorter time. The same thing was observed also with the ova of *Pleuronectes microcephalus* and others. But these experiments are not sufficiently rigid to prove that the too low density of the water, *i. e.* the sinking of the ova, was the sole cause of the death of the ova in unsuccessful experiments. It may, however, be pointed out that in my experiments the ova were first fertilized in water much denser than themselves, and remained in this some time before they were transferred to water of less specific gravity in which they sank, and a change of density like this after fertilization may possibly be fatal, when if the ova were shed and fertilized at the beginning in water in which they sank they would live and develop normally. This can only be decided by further experiments directed specially to this point.

The specific gravity of mackerel ova fertilized in the water of the open sea where the parents were captured is 1·0265 at the maximum. In water of a specific gravity of 1·0263 a few out of a large number of ova remained at the surface; at a specific gravity of 1·026 the ova remained suspended at various depths for some time, and one or two rose to the surface, while at 1·0257 all the ova sank rapidly. Thus the specific gravity of different individual ova varies slightly within narrow limits; a few were observed to have a specific gravity of less than 1·026, but the great majority are heavier than 1·0263, and none are heavier, at least at early stages of development, than 1·0265, or lighter than 1·0259.

Development.—The ovum of the mackerel after fertilization is spherical and transparent, and has a diameter of 1·22 mm. In the early stages of segmentation the ovum is not perfectly spherical, because the principal diameter, passing through the centre of the blastoderm, is a little longer than the others, owing to the slight pressure of the prominent blastoderm on the envelope (fig. 16). The yolk is homogeneous and colourless; at its surface is a large oil-globule, also colourless, having a diameter of ·32 to ·33 mm. The blastodisc, and the blastoderm at the commencement of segmentation, has a slightly yellow colour, which disappears later. The envelope is thin, and I have not noticed any sculpturing or inequalities on its outer surface. The perivitelline space is small, at the stage referred to, consisting as usual of only a ring-shaped cavity in the depression between the blastoderm and the yolk; the rest of the ovum is in contact with the inner surface of the envelope.

The oil-globule moves with perfect freedom at the surface of the yolk, which proves that the latter substance is a liquid of very slight tenacity. When the ovum is floating freely in water the blastoderm is at the lowest pole, and the yolk at the uppermost. When the ovum is placed upon a slide, whatever be the position of the blastoderm, the oil-globule rises to the uppermost pole; the blastoderm is the heaviest portion of the ovum, the oil-globule the lightest. On the slide the position of the blastoderm is proved to be fixed in relation to the position of the egg envelope, but the oil-globule remains free and rises to the pole which is vertically highest under the action of gravity. Even when the blastoderm is placed uppermost the oil-globule passes freely beneath it and rests below its centre. Thus it is evident that the yolk is to be regarded as a liquid enclosed within a layer of protoplasm continuous with the blastoderm, and at the surface of this liquid next to the protoplasmic layer moves the oil-globule.

The blastoderm spreads out, and the segmentation cavity, embryonic rudiment, and embryonic ring are formed in the usual way. At the temperature of about 13·5° C. the sixteen-cell stage is reached in about seven hours, and the segmentation cavity is formed before the end of the first day (twenty-four hours). On the second day the growth of the blastoderm over the yolk takes place. During all this time until the envelopment of the yolk is completed the oil-globule remains movable (figs. 17 and 18), but as soon as the yolk is completely covered by the blastoderm the oil-globule becomes fixed in a position ventral to the posterior end of the embryo (figs. 19, 22, 24). This fixture is effected by the periblast, and is a fact which deserves the greatest attention. The oil-globule seems to belong entirely to the yolk, and the periblast grows with the blastoderm outside the yolk. Why then should it grow in between the oil-globule and the yolk, separating the two and fixing the former in one position? In its new condition the oil-globule projects slightly beyond the general surface of the yolk, which is depressed in its immediate neighbourhood. Thus there is a cavity round the projecting part of the oil-globule. This projecting part comes into contact with the blastoderm, which is here composed only of epiblast; the cavity belongs, of course, to the segmentation cavity. The question arises whether the periblast furnishes a covering to the outer surface of the oil-globule as well as to the deeper side. It probably does, but I cannot say with certainty.

The time when the enclosure of the yolk is completed varies of course with the temperature, but in my experiments it was effected before the end of the second day. The differentiation of the organs in the dorsal part of the embryo begins before it is complete, and proceeds rapidly during the third day. Fig. 20 shows the stage reached about the middle of the third day; seven mesoblastic somites are distinctly seen, the eyes are indicated, and Kupffer's vesicle has appeared. On the fourth day (figs. 21, 22, 23) the crystalline lens, the auditory vesicle, the heart, the intestine, and the notochord are formed, and pigment appears in the skin. This pigment is confined to the sides of the embryo, and to the deep surface of the oil-globule; there is none on the surface of the yolk; the pigment consists entirely of black dendritic chromatophores. The development of these chromatophores in the periblast covering the oil-globule on its deeper surface is another fact in connection with the oil-globule which deserves special attention. I have described the development of chromatophores in the periblast covering the anterior part of the yolk in *Pleuronectes microcephalus*, and these connected with the oil-globule in the mackerel are in homologous relations, but it is curious that they should be confined to the surface of the oil-globule and absent from the rest of the yolk.

Fig. 24 shows the condition reached on the fifth day; all the organs are more developed, and the notochord is seen to be multi-columnar. Pigment is still absent from the periblast covering the surface of the yolk, except over the surface of the oil-globule. But green chromatophores have appeared in addition to the black, and are confined to two small groups on each side, one behind the eye, the other at the base of the tail. The latter organ has begun to grow out at the posterior end of the embryo.

Some ova fertilized on June 29th, hatched on July 4th, the sixth day, at a temperature of 14·5° C. I have not been able to give a figure of the larva for reasons stated above, and can only give a few notes of its characters. The distribution of the pigment is much the same as in fig. 24; the notochord is multi-columnar, the mouth not open, the anus is immediately behind the yolk.

The special development of chromatophores round the oil-globule is not a peculiarity of the mackerel, but seems to occur to a great or less extent in all ova which contain oil-globules, especially if there is only a single one present. But so far as I am aware, attention has not hitherto been called to the peculiar position of this pigment on the deeper side of the oil-globule, though it probably has the same relative position in other species.

Historical and Comparative.—Some valuable information and deductions concerning the life-history of the mackerel are contained in a report made by Prof. G. O. Sars to the Department of the Interior of the Norwegian Government. Prof. Sars carried on investigations of the Norwegian fisheries for a series of years from 1864 to 1878, at the request of the Government, and his reports have been officially published from time to time at Christiania. The whole series was finally published in one volume in 1879. But to the English reader they are more easily available in the translations published in the Report of the United States Commissioner of Fish and Fisheries for 1877. In the report of Prof. Sars for 1875 he states that he made some preliminary investigations of the spawning of the mackerel during a zoological tour in the summer of 1865. He says that this fish spawns at the surface of the water, near or far from the coast, and that the roe floats near the surface and there goes through all the stages of its development; that the spawning period is as a general rule the first half of July; that the ova when shed are small beads as clear as crystal, which float near the surface as long as they are alive; that the ova are of about the same size as those of the cod or a little larger, but are distinguished from these by a large and very distinct and clear oil-bladder near the upper pole; that he obtained the fertilized ova from the sea by means of a fine net, and was able to keep these during development until they hatched. He believes that by the end of one year the young fish are about as long as the finger, that in two years they grow to the size of a common herring, and at the end of three years are full-grown and spawn themselves; that during the first two years they remain near shore, roaming about in the open water.

With regard to the habitat, the home of the mackerel, Prof. Sars, rightly no doubt, considers that it extends in the eastern part of the North Atlantic along the whole western coast of Europe from the Orkney Islands and the north coast of Scotland to the Metiterranean and southward to the Canary Islands. It occurs on the southern and western coasts of Norway, on all the other coasts of the North Sea, on the western coast of Great Britain, round Ireland, in the Channel, on the coasts of France, Spain, and Portugal, and in the Mediterranean as far as the Black Sea. It also occurs on the Atlantic Coast of North America from Labrador to Cape Hatteras (see: *Materials for a History of the Mackerel Fishery,* U.S. Fish. Comm. Report for 1881). Prof. Sars rightly condemns the erroneous notions that have been held concerning the habits of the mackerel. Some have supposed that there is an enormous annual migration for spawning purposes from the sea round the North Pole; others, especially the fishermen, that the fish in winter remained at the bottom in a torpid condition, and, what is still more strange, blind. Prof. Sars believes, as is now generally held for all pelagic fish, that they approach the coast chiefly in order to spawn, and at other times are scattered at greater distances from the shore, or in the ocean, but always in an active pelagic condition. He thinks it probable that not all the mackerel taken on the coasts of the North Sea pass their whole life in that area, but that many enter it from the north or through the Channel. It is certain that in the neighbourhood of Plymouth mackerel are often caught in greater or less numbers all the year round, though there is generally little fishing immediately after the spawning time, *i. e.* at the end of July and the beginning of August.

It is stated in the paper already referred to, "Materials for a History of the Mackerel Fishery," that the spawning season on the Coast of New England coincides with that observed on the British Coasts, occurring in May and June in Massachusetts Bay, and in June in the Gulf of St. Lawrence. As we have seen, Professor Sars states that the spawning of the mackerel does not begin on the west coast of Norway until the beginning of July, and that it is finished about the middle of that month. He may not have been able to make sufficient observations, as at Plymouth the spawning period lasts more than one month.

It may well be that the season is a little later off Norway, for I find that the surface temperature on July 22nd in the Foldenfjord, 64° 34′ N. latitude., in 1880 was 11·4° C., which is slightly less than the temperature off the Eddystone on June 12th, 1888. Thus the spawning season of the mackerel is doubtless inseparably connected with a certain range of temperature, though the connection may be an indirect one, through the relation of the temperature of the sea to the mackerel's food.

In the family Scombridæ, besides the mackerel are included the various genera of tunnies, which are mostly of very large size, and the tropical sucking-fish, *Echeneis remora.* Of these, so far as I know, the ova and development have not been investigated, but in all probability their ova are buoyant and pelagic. On the Atlantic coast of North America another species of the family besides the common mackerel occurs, and is the object of a regular and valuable fishery in Chesapeake Bay, at Sandy Hook, Southern Long Island, and Narragansett Bay. This species is the *Cybium maculatum* (Mitchel), Agass. It is chiefly captured in fixed gill-nets, not in drift-nets or seines to so great an extent. Its spawning and development have been investigated by J. A. Ryder, a naturalist of the United States Fish Commission, and an account of its fishery is given by R. Edward Earll. Its ova are pelagic and closely similar in all respects to those of *Scomber scomber*, but somewhat smaller. On the coast of Virginia (Mobjack Bay, Chesapeake Bay) it spawns in July. Ryder does not mention the mobility of the oil-globule; he states that it is fixed and to its position ascribes the buoyancy of the egg, and the position of the egg when floating. Probably the oil-globule is movable nevertheless, and there are several floating eggs which have no oil-globule. Ryder describes the subsequent formation of a mantle of cells, "apparently of hypoblastic origin," round the oil-globule, and says that by the time the young fish is ready to hatch, the covering of the oil-sphere is found to be more or less covered with pigment which seems to have been developed in the cellular mantle. This refers to the same processes in the history of the oil-globule as I have described in the mackerel, but the mantle round the globule is certainly not made of hypoblastic cells, but of the periblastic syncytium, from which the pigment-cells are developed. The development in Cybium is extremely rapid, hatching taking place about twenty-four after fertilization; the temperature of the water in which the eggs were kept artificially, or of the sea in which they are shed naturally, is not stated by Ryder. The mouth was formed about twenty-four hours after hatching, by which time the yolk was almost entirely absorbed. Some of the larvæ were kept alive till the sixth day after hatching.

BLENNIUS OCELLARIS.

On July 10th I received at the Laboratory a large hollow bone, probably the femur of an ox, affixed to the sides of the cavity of which was a single layer of adhesive ova of an orange-red colour; this was forwarded by Mr. Dunn, of Mevagissey, who had obtained it from some fishermen. It was brought up by a long line fifteen miles south of Deadman Point, Cornwall, having been caught by one of the hooks. In the letter sent at the time Mr. Dunn stated that the fishermen said that when the bone was taken there was a fish in the cavity of the bone, supposed to be guarding the eggs, but that the fish had escaped and fallen overboard. The next day, however, Mr. Dunn forwarded a fish which he said was the one that had been seen in the cavity of the bone, the fishermen having found it at the bottom of their boat and recognised it as the same. This fish was a specimen of *Blennius ocellaris*, L., and in all probability the ova belonged to it.

The character of the ovum is shown in Fig. 25. Its diameter, measured in a direction parallel to the surface of attachment, is 1·2 mm. The embryo was distinctly formed and somewhat advanced in development, the heart having begun to beat ; but this organ lying on the surface of the yolk anterior to the embryo is not shown in the figure. The yolk is of an orange-red colour and made up of separate minute yolk-spherules ; it also contains near the tail of the embryo a number of oil-globules of different sizes. The tissues of the embryo were very transparent. The chromatophores are limited in number, intensely black in colour, and confined to the dorsal portion of the yolk-sac near the tail of the embryo.

Blennius galerita, and *Blennius pholis* are stated by Day to have adhesive ova, the former depositing them on stones, the latter in holes in rocks, on the authority of Couch (Zoologist, 1846). *Centronotus gunnellus* has adhesive ova which adhere together and form a free round mass. *Zoarces viviparus* hatches its ova in its ovary and produces about fifty young at a time all alive and similar to the parent except in size (see my paper in Trans. Roy. Soc. Edin., 1886). Shore fishes, like fresh-water, fishes have usually adhesive ova, or in some cases heavy ova which sink to the bottom. Such ova usually have oil-globules, either a single one or several, and the yolk is always made up of minute yolk-spherules.

CALLIONYMUS LYRA (the Dragonet).

I have already referred to the ova of this species in connection with my observations on *Solea vulgaris,* and have stated that I identified the ova taken by the tow-net shown in figs. 26 and 27 as the ova of *Callionymus lyra.* I also mentioned that Raffaele denies altogether the existence of the hexagonal marking of the vitelline membrane in the Mediterranean species *C. festivus.* On the other hand, Raffaele found an exactly similar reticular marking of hexagonal meshes on the vitelline membrane of the fertilized ova of *Uranoscopus scaber,* and in the ovarian ova of *Saurus lacerta.* It is certainly somewhat inconsistent on the part of the Italian zoologist that he should assume that McIntosh mistook an epithelium for a marking of the vitelline membrane in *C. lyra,* and should affirm the existence of the marking in Saurus on evidence exactly equivalent to that on which McIntosh relied. Saurus is a genus of the Scopelidæ, which family belongs to the order Physostomi.

Leaving the question of *Saurus lacerta* entirely aside for the present, the similarity between the ova of *C. lyra* and Uranoscopus suggests some interesting possibilities with regard to the true systematic affinities of these two genera. Callionymus belongs to a group, Callionymina, which is classed by systematists in the family Gobiidæ, but which certainly forms an aberrant group of that family. Callionymus is extremely different from any of the typical Gobiidæ; it has a depressed form, no ventral sucker, has the eyes close together at the top of the head, in accordance with its habit of lying always on the sea-bottom on its flat ventral surface, and has a multiradiate spine resembling a riding spur directed backwards from its preoperculum. Uranoscopus similarly belongs to an aberrant group of the Trachinidæ, to which our common weevers, *Trachinus draco* and *vipera*, belong. All the Trachinidæ with few exceptions have a backward-pointing spine on the operculum. Uranoscopus possesses this spine, but whereas most Trachinidæ are compressed from side to side, Uranoscopus, as its name implies, is depressed from above downwards and has the two eyes directed upwards and placed on the upper flat surface of the head. The families Trachinidæ and Gobiidæ are widely separated by Günther, the former being placed among the Gobiiformes, the latter among the Cotto-scombriformes. Yet considering that the eggs have a rare peculiarity in common, and that there are several similarities of adult structure, it seems probable that Callionymus and Uranoscopus are closely allied, and that either the Callionymina ought to be included among the Trachinidæ instead of among the Gobiidæ, or that the Callionymina and Uranoscopina together form a single family, distinct both from the Gobies and the Weevers.

In support of this suggestion it is to be noted that the ova of typical Gobiidæ are adhesive, not pelagic like those of Callionymus, and that, although the ova of both Uranoscopus and Trachinus are pelagic, those of the former have the reticulate marking and no oil-globules, those of Trachinus have no marking and numerous oil-globules. The ova of Trachinus have been described and figured by George Brook in Lin. Soc. Journ., vol. xviii, 1884, and also by Raffaele in the paper so often cited.

CLUPEA PILCHARDUS (the Pilchard) AND CLUPEA SPRATTUS (the Sprat).

The ovum of the pilchard has never yet been obtained directly from the parent fish and artificially fertilized, and therefore the absolutely certain knowledge based on the examination of ova so obtained is still wanting. But it will be shown in the following that a definitely characterised ovum is known, which I have traced with all reasonable certainty to this species. The history of our knowledge on this subject is of much interest, and is an excellent example of the difficulty which may unexpectedly occur in the attempt to solve an apparently simple problem.

The question of the ova of the pilchard is closely connected with that of floating Clupeoid ova in general, and I will therefore give a brief summary of the history of this larger question. Some years ago the only species of Clupea whose eggs were known with certainty was the herring, *Clupea harengus.* The eggs of the herring are heavy and adhesive, and when expelled from the body of the fish they stick fast to anything they happen to fall upon. A detailed account of their structure and development was published by Prof. Kupffer in 1878 in the Jahresbericht der Commission zur Untersuchung der deutschen Meere for 1874–76. But before that herring spawn had been dredged from the sea-bottom near the Isle of May in the Firth of Forth. I myself studied the ova in the years 1883 and 1884, and published a paper on them in 1885.* In 1882 Alexander Agassiz described† a pelagic ovum (*i. e.* a floating one) which had a yolk entirely divided into small segments, and which produced a larva 5 mm. long, having a great resemblance to a larval herring. Agassiz at first thought these eggs must belong to some Clupeoid, but afterwards identified the larva as the young of *Osmerus mordax,* Gill. But the American *Osmerus mordax* is the same as the British *Osmerus eperlanus,* and this species was discovered by myself‡ to have adhesive ova with a peculiar method of adhesion, and to spawn in almost fresh water in the upper parts of estuaries. V. Hensen§ in 1883 described a similar ovum, which he took in the tow-net in the Baltic near Kiel. This ovum, like that of Agassiz, had a segmented yolk and no oil-globules; its diameter was 1·24 mm., and the larva which hatched from it resembled a herring larva and had a length of 3·7 mm. In 1886|| I described a very similar ovum taken by the tow-net in the Firth of Forth; this likewise had a segmented yolk, and produced a herring-like larva. The dimensions of the ovum were ·94 by ·97 mm. diameter, and the larva was 3·63 mm. long. I concluded that this ovum came from the same species as Hensen's. The latter informed me by letter that he believed the ovum to belong to the sprat, *Clupea sprattus,* but I did not succeed in obtaining fertilized ova of the sprat for

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* *On the Significance of Kupffer's Vesicle, &c.,* Quart. Journ. Micr. Sci., 1885.

† *Young Stages of Osseous Fishes,* part iii, Proc. Amer. Acad. Arts and Sci., vol. xvii.

‡ Proc. Zool. Soc. Lond., 1886.

§ Vierter Bericht der Comm. Unters. deutschen Meere, II Abtheilung, Berlin, 1883.

|| Trans. Roy. Soc. Edinb. for Session 1885–86.

comparison. Lately, in 1887,* Hensen has stated that he obtained ova taken from the sprat and artificially fertilized, and found they agreed in all respects, both in size and structure, with the ova he got in the tow-net. There can be little doubt that my ova from the Firth of Forth were of the same species as Hensen's; my measurement of the ovum was somewhat smaller than his, but the length of the larva was almost exactly the same in the two cases. And it is also pretty certain that Agassiz' ovum found off the American coast belonged to some species of Clupea.

With regard to *Clupea pilchardus,* Couch long ago in 1865, in his Fishes of the British Islands, stated that the pilchard spawned at the surface of the sea. His account is as follows: "In April and May they are habitually prepared to shed their spawn, which they now do at a further distance from land and over deeper water than is the case at the warmer season of autumn, when again, early or later, they perform the same function, although we do not feel assured that they are the same fishes which thus perform the duty of procreation on both occasions." "I have reason to suppose that the spawn is shed at the surface, and mingled with it a large quantity of tenacious mucus in which it is kept floating while it is obtaining the vivifying influence of the light and warmth of the sun. My notes on this subject are that presently, after spawning, a sheet of jelly, enclosing myriads of enlarging grains of spawn, has been seen to extend several miles in length, and a mile or more in breadth over the surface of the sea." We shall see how far Couch was from a knowledge of the real spawn of the pilchard.

In a Report by Frank Buckland and Spencer Walpole, Commissioners for Sea-Fisheries, on the sea-fisheries of England and Wales, presented to Parliament and officially published in 1879, evidence concerning the spawning of the pilchard, given by Mr. Dunn, of Mevagissey, is recorded. In Appendix No. III to that Report, by Frank Buckland, the following quotation is given from a letter from Mr. Dunn: "On the 28th of May, 1871, I took a pilchard alive, and in the act of spawning, about twenty miles from land. With the help of my hands the fish deposited the remaining spawn into a bucket of sea-water. Immediately the spawn rose to the surface of the water with the buoyancy of cork, and instantly the eggs separated from each other. By the candle-light the globules appeared bright and almost transparent. After a few minutes they lost their buoyancy save just dipping under the surface, others floating an inch or two further down. In this state they continued for two hours, then a white speck showed itself in each globule,

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* Fünfter Bericht der Comm. Unters. deutschen Meere, Berlin, 1887.

and all sank to the bottom of the vessel." The eggs in this experiment were unfertilized, no milt was added to them.

In Day's work, Fishes of Great Britain and Ireland, 1880–1884, it is stated that Mr. Dunn observed that the pilchard appears to breed at two seasons of the year, May and June, and also in December, and the young are first seen in September, three or four inches in length. On January 16th, 1882, Mr. Dunn observed the fish returning to the bays shotten.

On the 15th October, 1887, in reply to inquiries of mine, I received a courteous letter from Mr. Dunn, in which he said he was certain that some pilchards spawn late in December and early in January, and even up to March, the winter spawning extending thus over some months. He said that in summer some pilchards spawn in May, the majority in June, and others in August. He also said that in some seasons spawn, which he believed to come from the pilchard, was seen floating in immense tracts on the surface of the sea.

This continuous sheet of spawn mentioned by both Couch and Mr. Dunn, can only be the spawn of *Lophius piscatorius*, the angler or devil-fish, whose spawn is known to be contained in an extended sheet of gelatinous material. It is fully described by Agassiz and Whitman in their memoir already cited, on the Pelagic Stages of Osseous Fishes. I have not myself met with this spawn of Lophius off the coast of Devon and Cornwall, but as the angler is common enough in the neighbourhood, I have no doubt that it has been seen by fishermen and erroneously identified by Couch and Mr. Dunn as the spawn of the pilchard.

Meanwhile, before any naturalist had identified ova of the pilchard the eggs of another species of the family Clupeidæ, namely, the anchovy, *Engraulis encrasicholus*, were examined and found to be pelagic. This discovery was made by K. F. Wenckebach, of Amsterdam,* and published only in 1887. I have not seen the original paper, but the Italian zoologist Raffaele gives a description, with figures, of the ova of the anchovy and the young stages of the fish, from studies he was able to make upon them at the Zoological Station at Naples. Fortunately, there is no danger of confounding the eggs of the anchovy with those of the pilchard or sprat. The egg of the anchovy, like the others, has the yolk divided into segments, but instead of being spherical like the others it is much elongated, so as to have the shape of a sausage.

Raffaele gives a description and figures of two other kinds of floating eggs, which, having a segmented yolk, are recognised by him as belonging to species of the herring family; he obtained these

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* *De embryonale ontwikkeling van de Ansjovis* (*Engraulis encrasicholus*), Verh. Akad. Amsterdam, Deel 26, 1887.

from the open sea by means of the tow-net, and has not taken directly from the fish, eggs that could be identified with them. He therefore speaks of them as Clupea species A, and Clupea species B. The first of these he believes to be the ovum of the pilchard. It is well known that the pilchard and the sardine are the same fish at different sizes, and sardines are common enough in the Gulf of Naples. This species, A, is an ovum of spherical shape varying from 1·50 to 1·70 mm. in diameter. Compared with the majority of floating ova, it has this peculiarity, that the space between the egg proper and its envelope is exceedingly large; the egg itself inside this space has a diameter of only ·80 to ·90 mm. In the yolk is a single oil-globule ·16 mm. in diameter. The segments of the yolk have a polygonal form due to their mutual pressure. The egg hatched in four or five days at a temperature of 9° to 12° C., and the larva resembled that of other pelagic Clupeoid ova, *e. g.* the sprat, but its length is not given.

The ovum of species B differs very slightly from that of species A. It is a little smaller in the diameter of the egg envelope, which is 1·20 to 1·40 mm. It has, like the other, a segmented yolk containing a single oil-globule which is ·121 mm. in diameter, slightly smaller than in the previous case. The oil-globule has a slightly yellow colour, the yolk and embryo have a faint smoky tint, which colours are absent in species A. The only other difference is that in the newly-hatched larva of species B the oil-globule is in the centre of the lower margin of the yolk, in species A it is at the posterior end of the yolk. Species A was found in the winter, Species B in summer and autumn.

My own Inquiries.—From the beginning of September, 1887, I examined at Plymouth the pilchards landed by drift-net boats from time to time, but never found any generative organs which were quite ripe or very nearly ripe from that time till the following summer. In October, 1887, the ovaries and spermaries seemed to be about half developed in a few specimens, and it is possible, even probable, as will be seen, that some individuals spawn late in the autumn. I found no change in the condition of the fish up till the end of January: the fish were usually 7½ to 8½ inches in length. In the early part of 1888 I was too much occupied with other fish to pay a great deal of attention to pilchards, but there was no regular fishing for them going on, and scarcely any were caught. I was told by a pilchard fisherman that these fish were found in spawning condition in April and May, but he did not think at any other time of the year. Afterwards I was told by mackerel fishermen that they often in summer got large pilchards which were meshed along with mackerel in their mackerel drift-nets, and that these were always soft and ripe, with spawn and milt running out of them. I found by actual experience that this was perfectly true. On June 2nd, 1888, two pilchards were brought up to me from a boat which had caught them in mackerel nets five miles south-west of the Eddystone. These were perfectly ripe, the whole ovary, as in the herring, containing nothing but ripe eggs which escaped on the slightest pressure. These eggs were, of course, dead, and as these were the only two pilchards taken it was impossible to fertilize any of them at the time of capture. But the eggs were fresh enough to show in some degree their structure, and I made a drawing of one which is shown in fig. 28. This shows that there is but a single oil-globule, and that the yolk is made up of spherical vesicles. The diameter measures ·98 mm., that of the oil-globule ·16 mm. Of course the envelope in the ovarian egg is everywhere in contact with the yolk. Several times in June and July one or two pilchards were taken by mackerel fishermen who were endeavouring to get fertilized pilchard spawn for me, but they never succeeded in getting ripe males and ripe females at the same time. Sometimes they got a single ripe male, at others two or three ripe females. One boat shot at my request two pilchard nets, which have a smaller mesh, with its fleet of mackerel nets, but even this did not succeed. One of these occasional ripe specimens, a female, was caught as late as October 17th, and the skipper who took it pressed the ripe ova into a bottle of clean sea-water, and gave them to me the next day when he returned to port. But when I got them the ova were already dead and lying at the bottom of the jar, and on examination I found that the yolk was decomposed. I could form no conclusions from these as to the normal extent of the perivitelline space.

In 1887 I had taken pelagic ova in the tow-net, which, from the probability of the ovum with segmented yolk taken in the Firth of Forth being that of *Clupea sprattus*, I guessed were those of the pilchard. The structure of these ova is shown in fig. 29. I took some in Whitsand Bay, August 11th, and did not meet with them again till November 9th, when I found a few in a tow-net worked from a trawler to the south-east of the Eddystone. On both occasions there were only five or six specimens of this particular ovum. Its diameter measured in one case 1·72 mm., in another 1·65, including the envelope. The space between the latter and the yolk was extremely large, and the yolk itself measured ·85 mm. in diameter in the first case, ·95 mm. in the second. The yolk was composed of polygonal segments divided by curved surfaces, and contained a single oil-globule ·16 mm. in diameter. This ovum, therefore, agrees in every respect both of size and structure with

Raffaele's Clupea species A. Of those taken on November 9th I was successful in hatching some, and the appearance of the larva produced is shown in fig. 30. This larva was 3·8 mm. in length, and the oil-globule was at the posterior and lower side of the yolk, thus also agreeing with the larva of Raffaele's species A. There can be no doubt that these ova of mine and those described by Raffaele as species A belong to the same species of fish, and the character of the unfertilized ovum taken directly from the pilchard, having a diameter corresponding to that of the yolk in the tow-net specimens, and an oil-globule of exactly the same size as that in the latter, is sufficient evidence that these ova from the tow-net are the ova of *Clupea pilchardus*. Fig. 30, then, shows the structure of the larva of the pilchard. Like that of the herring and sprat it has a unicolumnar notochord, that is, a notochord with a single linear series of cubical vacuoles. At the time of hatching, pigment, as in the herring, is altogether absent, even in the choroid of the eyes. The intestine extends far behind the yolk, and the anus is near the end of the tail. A comparison of figs. 28 and 29 shows that the ovarian ovum of the pilchard is more closely similar to the fertilized ovum of the herring than the pilchard ovum in its pelagic state after fertilization; in the ovarian ovum the yolk elements or segments are still spherical vesicles as in the herring, while in the fertilized ovum these segments have come into close contact with one another, and so become more polygonal.

These observations show, as was previously stated by Mr. Dunn, that pilchards spawn far out at sea, and that the pilchard fishery consists exclusively in the capture of fish which are not spawning, of fish in which the generative organs are not even approaching the ripe condition. The shoals of pilchards which are caught in drift-nets not far from shore in autumn, winter, and spring, approach the coast to feed and not to spawn; they are either shotten fish or young fish which have never spawned. It is otherwise with the mackerel and the herring; mackerel are, as I have shown in this paper, caught as abundantly during their spawning period as at any other time, while the winter fishery for herrings near Plymouth and all the other great herring fisheries that I know of consist chiefly in the capture of spawning shoals, although there are productive fisheries of immature herring which remain some time in shore waters for the purpose of feeding.

My evidence, as far as it goes, does not favour the theory that there are two separate periods in the year at which pilchards spawn; it shows that ripe specimens occur to the south of the Eddystone occasionally from the beginning of June to the middle of October, and as it is reasonable to suppose that the pilchard, like the herring, spawns in shoals, we must conclude that these shoals of ripe fish are to be sought at greater distances from shore than the region a few miles south of the Eddystone where the isolated individuals were taken. This conclusion is supported by the paucity of the pilchard ova taken in the tow-net, and it does not permit very sanguine hopes of the practicability of artificially propagating the pilchard on a large scale. But it must be mentioned that, according to the positive statements of the mackerel fishermen, the number of spawning pilchards taken in their nets was extraordinarily small last season; that it is not unusual for fifty or more ripe specimens to be taken among a single catch of mackerel.

Another kind of buoyant Clupeoid ovum occurs near Plymouth. This is shown in fig. 31. It is 1·01 or 1·02 mm. in diameter, and has the small perivitelline space characteristic of the majority of pelagic ova. The yolk has the same segmented structure as that of the pilchard ovum but has no oil-globule. At the stage shown in fig. 31 black chromatophores were conspicuous near the dorsal median line of the embryo. The larva hatched from one of these ova is shown in fig. 32. Its length was 3·07 mm., which is less than that of the pilchard larva and less than that of the larva previously described by Hensen and myself. But as the length of a hatched larva probably varies, I think that in all probability this ovum and larva belong to *Clupea sprattus*, the sprat, which regularly occurs in Plymouth Sound in winter. This kind of ovum was taken in small numbers just outside the Sound, to the east of Penlee Point, on January 28th and 30th, 1888.

PELAGIC OVA TAKEN IN THE TOW-NET.

Some of these, identified as those of the pilchard, sprat, sole, and dragonet, have already been described, but besides these many other kinds were obtained which could be identified with more or less certainty from the descriptions and figures already published by myself and others of artificially fertilized ova taken directly from the parent fish. Some ova taken near the Rame Head on February 6th, 1888, measuring 1·36 in one diameter, 1·44 in another, and having an entirely homogeneous yolk, were probably the ova of *Pleuronectes microcephalus*, of which some specimens probably begin to spawn in February.

PLEURONECTES PLATESSA (the Plaice).

An ovum of Pleuronectid type of very large size, obtained January 21st, 1888, eight miles south of the Mewstone, probably came from this species. It measured 2·13 mm. in diameter, had a number of dendritic black chromatophores on the body of the embryo; the tail was fully developed and the larva almost ready to hatch. The ovum of the plaice was described in my paper in the Trans. Roy. Soc. Edin., vol. xxxiii, part 1; the measurement I there gave was 1·95 mm., but 2·13 mm. is not beyond the limit of individual variation.

GADUS MERLANGUS (the Whiting).

Ova obtained February 6th, 1888, off the Rame Head at the entrance to Plymouth Sound. Their size was 1·23 mm. in diameter, they had a homogeneous yolk without oil-globules. I gave a description of the ova of this species in 1885* from artificially fertilized ova, and stated their diameter as 1·25 mm. I did not figure the hatched larva in that paper, and therefore now give figures of one stage of the ovum, and of the larva which hatched from one of these tow-net specimens. The larva is 3·67 mm. long, and the dendritic chromatophores are confined to the body of the fish absent from the median primordial fin, and from the surface of the yolk. The rectum, as in all species of Gadus, does not extend to the edge of the ventral part of the median fin, but ends blindly close to the body. Figs. 33, 34.

I found the whiting perfectly ripe at Mount's Bay on March 7th, although I did not take any artificially fertilized ova, and there is no doubt that off Plymouth the species spawns also in February.

GADUS LUSCUS (the Pouting).

Another ovum similar to the previous, but measuring 1·13 mm. in diameter, was obtained eight miles south of the Mewstone on January 20th. From it a larva hatched on January 23rd, which obviously belonged to a species of Gadus, having similar characters to the one assigned to the whiting. It is represented in fig. 35. Its length was 2·97 mm. I have identified it provisionally as the larva of *Gadus luscus,* the eggs of which species I have never taken directly from the fish.

MOTELLA, SP.? (the Rocklings).

The ova and larvæ shown in figs. 36, 37 I find it difficult to identify, but they probably belong to the genus Motella. The blind rectum,

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* *Relations of Yolk to Gastrula in Teleosteans,* Quart. Journ. of Micr. Sci., 1885.

terminating before reaching the edge of the primordial fin, shows that the larva is one of the cod family. The hake, *Merluccius vulgaris,* has been found to have a single oil-globule, but the present ovum has a diameter of ·78 mm., that of the hake is larger, ·94 to 1·03 mm. *Motella tricirrata* has, according to Raffaele, an ovum measuring ·74 mm., while the ovum of *Motella mustela,* according to George Brook (Journ. Linn. Soc., 1884), measures ·65 to ·73 mm. Another feature characteristic of Motella and present in the ovum under consideration is the presence in the earliest stage of several oil-globules which afterwards fuse into one. This ovum was obtained in considerable numbers to the east of Penlee Point on January 28th and 30th, 1888. Some of those taken on the latter date hatched on February 2nd. The length of the larva was 1·98 mm., and it had black pigment only which was confined to the body of the fish, and absent from the fin and the yolk-sac. It is not unlikely that these ova really are those of *Motella tricirrata ;* the difference between their size and that given by Raffaele is very slight. On May 31st I obtained in the tow-net two specimens of a young fish 17 mm. long, which agrees with descriptions given of the young *Motella tricirrata.* The chief characteristic of this young fish (fig. 39) is the great length of the ventral fins which extend back to the anus, and the intense black colour of their terminal third. Another curious point is that the caudal fin, although it has apparently attained its final form, is almost completely homocercal, being supported by fin rays which have a symmetrical relation to about eight terminal vertebræ. The sides of these little fish had a very bright silvery glitter. There was a small barbel on the symphysis of the lower jaw. This young fish is identical with that described by Couch (vol. iii, p. 113) as Thompson's Midge, which together with the *Couchia argentata* of Günther (Catalogue, vol. iv, p. 363), is identified by Day as the young of the three-bearded rockling *Motella tricirrata.* Agassiz (Young Stages of Osseous Fishes, pt. 3) describes stages of a young fish very similar to the one I have described, and identifies it as *Motella argentea,* Rhein., but I do not know if this species is the same as *Motella tricirrata.* The young of *Motella mustela,* the five-bearded rockling, is known as the mackerel midge, which has already five barbels, but its younger stages may well be indistinguishable from those of *Motella tricirrata.* These young Motella are said to form the principal food of the mackerel in May, but I have not verified this at Plymouth.

I found one specimen of hake perfectly ripe on July 6th, so that this species spawns at Plymouth in summer; Raffaele found it spawning at Naples in May.

I have taken other kinds of ova in the tow-net, but have not been able to identify them with any certainty. The ova most difficult to identify are those which have a homogeneous yolk with a single oil-globule, because there are so very many species which have ova of this character differing only, in the early stages, in size, and sometimes not even in that respect. Further and more minute study of the larvæ will probably enable us to distinguish the species to which they belong, but before hatching this is almost impossible. It has been seen already in this paper that this type of ovum is common to the families Scombridæ (mackerel), Carangidæ (cuckoo), many Gadidæ (hake, rockling), many Pleuronectidæ (Arnoglossus, Rhombus). And Raffaele describes ova of the same kind from the bass, *Labrax lupus* (Percidæ), and from some of the sea-breams *Pagellus erythrinus*, &c. (Sparidæ) ; some of the wrasses (Labridæ), namely, Coris and Julis, have also similar ova.

It is evident that a great deal still remains to be done before an adequate knowledge of the development and growth of the Plymouth fishes is obtained. But the researches I have described in this paper have been, and future work will be, greatly facilitated by Raffaele's admirable memoir so often quoted in the preceding pages. The extent to which the Italian naturalist's results apply to the fish-fauna of Plymouth, shows how closely connected faunalogically are the south coast of Britain and the Mediterranean.

A Hypothesis concerning Oil-Globules in Pelagic Teleostean Ova.

In considering the question why some pelagic ova have separate oil-globules in their yolk while others have none at all, I have noticed a connection between the presence of these separate masses of fatty matter and the normal quantity of oil in the body of the parent fish. Whenever the adult has a large quantity of oil in its tissues the ova possess one or more oil-globules in the yolk. At least this seems obvious in some cases. In both the herring and the pilchard the yolk is completely vesicular ; this is a character common to all species of the genus *Clupea ;* but the pilchard ovum has a large oil-globule, the herring ovum has none ; and it is certain that the adult pilchard possesses more oil in its tissues than the herring. The mackerel also is a rich oily fish, and its ovum has an oil-globule, while the species of Pleuronectes and Gadus have comparatively dry flesh, and their ova have no oil-globules. The sole is richer in oil than the plaice, and the former has oil-globules while the latter is destitute of them.

There are two ways of regarding this fact if it be one. We may suppose that the excess of oil runs over as it were into the ova, without having any great importance to the latter; or we may suppose that as the tissues of the adult are oily, it is necessary that the tissues of the embryo should be supplied with abundance of oil in order to develop normally. But perhaps the truth lies in the union of these two suppositions, that the excess of oil in the tissues of the parents extends into the ovum, and during the development of the latter supplies the embryo with an abundance of fat which is necessary to its constitution. But none of these hypotheses explain why in many cases ova provided with oil-globules have a greater specific gravity than those that are without them; a difference which must depend on a greater density of the protoplasm and of the yolk.

THE DEVELOPMENT OF THE VASCULAR SYSTEM AND CŒLOM IN PELAGIC OVA OF TELEOSTEI.

In a great many pelagic Teleostean embryos at the time of hatching the heart consists of a tube which opens posteriorly out of a wide space between the yolk, or more accurately between the surface of the periblast and the wall of the yolk-sac, which wall consists solely of a layer of epiblastic cells. The heart itself is surrounded by another cavity which is separated from the space first mentioned by a thin membrane, which passes on the one hand into the lips of the posterior aperture of the heart, and on the other into the body wall ventrally, into the tissue beneath the pharynx dorsally. The space out of which the heart opens contains blood, *i.e.* a colourless fluid containing at first colourless corpuscles, which at a later stage become red corpuscles. The blood is carried by the pulsations of the heart out of the space round the yolk into the cavity of the heart.

The cavity round the periblast, which communicates with the heart, exists at an earlier stage, before hatching, as a space between the epiblast of the anterior part of the yolk-sac and the periblast. And this is the same space which exists at a still earlier stage before the yolk has been enveloped by the blastoderm, between the epiblast and the periblast in the central part of the blastoderm, that is, over all the region of the latter which is not occupied by the embryonic rudiment and the embryonic ring. This space, in fact, is the earliest to appear in the ovum, and is nothing more or less than the segmentation cavity.

To consider now the space which surrounds the heart, and which is entirely separated from the space which communicates with the heart. This cavity round the heart is simply a portion of the true body-cavity or cœlom. The heart with this cavity develops shortly before hatching out of a solid mass of mesoblast cells situated below the pharynx, and continuous on either side with the lateral mesoblastic plates which lie on either side of the notochord. I have not studied the histological process by which the heart itself is formed. Suffice it to say that it is produced by the formation of the central mesoblastic cells into a tube, which, as soon as it has a lumen, communicates with the space between the ventral epiblastic body wall and the periblast. The cavity in which the tubular heart is contained is due to a splitting of the mesoblast, and is continuous superiorly and posteriorly with the cavity formed on each side of the embryo by the splitting of the lateral mesoblastic plates. The cavity containing the heart is in reality the first part of the ventral region of the body-cavity to be formed. A section farther back, through the centre of the yolk-sac at the stage immediately after hatching, shows a cavity on each side of the embryo in the mesoblastic plates; the splanchnic mesoblast forms the roof of the cavity between the periblast and the wall of the yolk-sac. The mesoblast only extends a little way from the embryo, so that laterally and ventrally the wall of the yolk-sac is formed solely of epiblast. The lateral body-cavities communicate anteriorly with the ventral body-cavity which contains the heart.

What then does the blood space between periblast and wall of yolk-sac correspond to in those Teleostean ova which possess a vitelline circulation? Obviously the vitelline veins and their tributaries communicate with the posterior end of the heart, just as does the single extensive blood space in pelagic ova. This blood space corresponds, and in a sense is homologous with the cavities of the vitelline veins. Suppose the vitelline veins and their capillaries to open out sufficiently so as to coalesce, and we have a single space extending over the surface of the yolk and communicating with the posterior end of the heart. This supposed continuous space would then correspond with the venous space in the pelagic ovum in a general way; but would it correspond exactly? The vitelline veins, where they exist, are canals running through a layer of splanchnic mesoblast covering the periblast. Now, in a pelagic ovum the mesoblast is, as far as we can judge from our present knowledge, limited to the embryo and the embryonic ring, and at a later stage to a narrow region at the sides of the embryo, which region is derived from the embryonic ring after the latter has disappeared as such. The space, therefore, over the rest of the yolk between the periblast and the epiblast, *i. e.* the segmentation cavity, can only close at these early stages by contact occurring between the epiblast and periblast. Now, such contact seems to occur at the stage immediately after the enclosing of the yolk has taken place, but it is certain that at a slightly later stage the space is again open beneath the anterior end of the embryo, between the yolk and the epiblast forming the wall of the yolk-sac; and this space becomes the venous sinus out of which the heart opens. Thus it would seem that the venous sinus in the pelagic ovum, which corresponds to the vitelline veins in other ova, is bounded internally by the periblast, and externally by a layer of epiblast, and that it is a persistent segmentation cavity.

But if we look at the living newly-hatched larva of *Pl. microcephalus* (fig. 8) we see over the surface of the yolk black and yellow dendritic chromatophores. As these are continued over the anterior surface of the yolk-mass, and are not visible in the wall of the yolk-sac in front of the yolk, it follows that these chromatophores exist on the surface of the periblast and not on the inner surface of the epiblastic wall of the yolk-sac. Chromatophores are of course mesoblastic, and these in particular are, in all probability, developed *in situ* from the periblast, the nucleated protoplasm surrounding the yolk. It has been shown in various Vertebrate ova that the nucleated protoplasm of the yolk at early stages buds off cells which join the mesoblast. At this later stage in the Teleostean ovum the periblast forms mesoblastic pigment-cells, and also, as shown by Ryder and others, *blood-corpuscles.* But there is no evidence that there is any mesoblast on the internal surface of the wall of the yolk-sac; the venous sinus is bounded internally by periblast with a few chromatophores on its surface, externally by a layer of epiblast. It is obvious, on reflection, that all the yolk, with its periblast, after the formation of the definite hypoblast, is a part of the splanchnic mesoblast. But the interesting morphological peculiarity about the venous sinus in the Teleostean embryo is that it is the persistent segmentation cavity. The segmentation cavity may partially disappear by the contact of its walls, but it is not, as usually represented in the frog, obliterated by the growth of the mesoblast; and thus, when the sinus venosus appears it is not as a cavity or system of veins entirely surrounded by splanchnic mesoblast, but is the old segmentation cavity between the epiblastic ventral wall of the yolk-sac and the periblast. This periblast develops chromatophores on its surface, a process which is peculiarly well illustrated by the formation of pigment-cells round the oil-globule in the mackerel; and at a later stage, no doubt, the sinus venosus acquires mesoblastic walls all round it, but this is not till the yolk has been absorbed.

The opening of the posterior end of the heart into the cavity round the yolk looks very surprising at first sight, and as it is very conspicuous has attracted the attention of all who have studied the development of pelagic Teleostean ova. I have figured it myself in my paper on Teleostean eggs and larvæ published in the Transactions of the Royal Society of Edinburgh. Ryder described it in the cod larva (Ann. Rep. Comm. of Fisheries of U.S. for 1882), but gave what was a very natural but erroneous interpretation of it. He called the space round the heart the pericardiac space, which is true if taken etymologically but not morphologically. The venous cavity he called the segmentation cavity, which is partially true, and stated it was the same as the body-cavity, which is erroneous.

Lastly, Mr. A. E. Shipley has described the development of the heart in Petromyzon (Quart. Journ. Micros. Sc., Jan., 1887). His description of the development of the heart from mesoblast beneath the pharynx agrees with what I have described in Teleostei. He also states that the heart communicates posteriorly with the space beneath the ventral yolk-cells and the epidermis, and that such a space would be equivalent to part of the segmentation cavity. Thus the condition of things in Petromyzon is similar in these respects to that in pelagic Teleostean ova. But when Mr. Shipley says, "From the fact mentioned above that the mesoblast behind the heart has not split into somatic and splanchnic layers nor united ventrally, it will be seen that the cavity of the heart communicates posteriorly with the space between the ventral yolk-cells and the epidermis," I do not follow him. It seems to me to be a *non sequitur*,—the heart might remain closed posteriorly until the ventral mesoblast had developed in the region behind it.

Moreover, although in Petromyzon it may be true that the mesoblast behind the heart has not split into somatic and splanchnic layers, my preparations show that the proposition is not true for Teleostean larvæ, for I find that the mesoblastic plates behind the heart have split so as to form a cœlom, and the splanchnic layer forms a horizontal partition dorsally between the cœlom on each side and the blood space surrounding the yolk. And although it may be true in Petromyzon that the yolk-cells form the immediate boundary of the venous sinus internally, it is also possible that some mesoblastic cells exist on the surface of the yolk in that form, for Mr. Shipley has drawn his conclusions from the study of sections, and I was not at first able to perceive in sections the dendritic chromatophores I have described in the larva of the pelagic Teleostean ovum. My observations concerning this subject have been chiefly but not exclusively made on the ova and larvæ of *Pleuronectes microcephalus*.

DESCRIPTION OF PLATES I—VI,

Illustrating Mr. J. T. Cunningham's paper on the "Reproduction and Development of Teleostean Fishes occurring in the neighbourhood of Plymouth."

Reference Letters.

au. Auditory vesicle. *p.* Body-cavity. *e.* Eye. *ht.* Heart. *int.* Intestine. *k. v.* Kupffer's vesicle. *n.* Notochord. *s. v.* Sinus venosus. *o. g.* Oil-globules. *y. s.* Yolk-segments.

All the figures, except figs. 38 and 39, are drawn from living ova or larvæ, with the help of Zeiss's camera lucida, and, except where otherwise stated, with Zeiss's objective A and ocular 2. Sometimes the object was, when drawn, covered with a cover-glass, sometimes not, as specified in the description of each figure.

FIG. 1.—Ovum of *Capros aper*, fertilized August 15th, 1887, 6 p.m. Drawn August 16th, 10 a.m. (16 hours).

FIG. 2.—Same species, fertilized same time. Drawn August 17th, 1 p.m. (1 day 19 hours), without cover-glass.

FIG. 3.—Ovum of *Trigla gurnardus*, fertilized May 11th, 1888. Drawn May 13th, without cover-glass.

FIG. 4.—Ovum of *Trigla cuculus,* fertilized April 27th, 1 p.m. Drawn May 2nd, 4 p.m. (5 days 3 hours); cover-glass.

FIG. 5.—Same species, fertilized May 10th. Hatched and drawn May 19th (9 days). Zeiss a_3, oc. 2, camera, no cover-glass.

FIG. 6.—Ovum of *Pleuronectes microcephalus*, fertilized April 12th, 1 p.m. Drawn April 14th, 4.30 p.m. (2 days 3½ hours).

FIG. 7.—Same species, fertilized same time. Drawn April 17th, 6 p.m. (5 days 5 hours); cover-glass.

FIG. 8.—Same species, fertilized same time. Hatched and drawn April 19th (7 days). Zeiss a_3, oc. 2, camera, without cover-glass.

FIG. 9.—Same species, fertilized and hatched same dates. Drawn April 23rd (4 days after hatching), Zeiss a_3, oc. 2, camera, cover-glass.

FIG. 10.—Ovum of *Solea vulgaris,* living but unfertilized. Drawn March 8th, 5 p.m.; cover-glass.

FIG. 11.—Same species, fertilized May 16th, 4 p.m. Drawn May 19th (3 days), without cover-glass.

FIG. 12.—Same species, taken in tow-net at surface outside the end of Plymouth Breakwater, March 16th; cover-glass.

FIG. 13.—Same species, taken in tow-net on the east side of Plymouth Sound, April 18th; cover-glass.

FIG. 14.—Ovum of *Solea variegata,* pressed from the fish May 29th, unfertilized. Drawn after death, May 30th, without cover-glass.

FIG. 15.—Probably the same species, taken in tow-net south-east of Eddystone Light, July 17th; without cover-glass.

FIG. 16.—Ovum of *Scomber scomber*, fertilized May 24th, 3 a.m. Drawn same day, 10.30 a.m. (7½ hours; 13·5° C.), without cover-glass.

FIG. 17.—Same species, fertilized June 1st, 3 a.m. Drawn June 2nd, 11 a.m. (1 day 8 hours), without cover-glass.

FIG. 18.—Same species, fertilized May 26th, 2 a.m. Drawn May 27th, 5 p.m. (1 day 15 hours); no cover-glass.

FIG. 19.—Same species, fertilized May 24th, 3 a.m. Drawn May 25th, 1.30 p.m. (1 day 10½ hours); no cover-glass.

FIG. 20.—Same species, fertilized May 26th, 2 a.m. Drawn May 28th, 11.30 a.m. (2 days 9½ hours); no cover-glass.

FIG. 21.—Same species, fertilized same time as above. Drawn May 29th, 11 a.m. (3 days 9 hours), without cover-glass.

FIG. 22.—Same species, fertilized same time. Drawn May 29th, 5 p.m. (3 days 15 hours), with cover-glass.

FIG. 23.—Same species, fertilized same time. Drawn May 29th, 1.30 p.m., with cover-glass.

FIG. 24.—Same species, fertilized same time. Drawn May 30th, 5 p.m. (4 days 15 hours), with cover-glass.

FIG. 25.—Ovum of *Blennius ocellaris* adhering to ox-bone. Drawn in living condition, without cover-glass, July 10th, 1888.

FIG. 26.—Ovum taken in tow-net in Plymouth Sound, February 1st, 1888; no cover-glass. Optical section. Probably *Callionymus lyra*.

FIG. 27.—Same ovum, surface view, showing the marking of the vitelline membrane.

FIG. 28.—Ovum pressed from a ripe female pilchard when the fish was dead.

FIG. 29.—Ovum of the pilchard at an advanced stage of development, from tow-net August 11th, 1887.

FIG. 30.—Newly-hatched larva of same species, from an ovum taken in tow-net November 9th, 1887.

FIG. 31.—Ovum of the sprat, taken in tow-net January 28th, 1888.

FIG. 32.—Newly-hatched larva of same species, from an ovum taken in tow-net January 30th, 1888.

FIG. 33.—Ovum taken in tow-net February 6th, 1888. Drawn February 9th, 1888. Zeiss a_3, oc. 3, camera; no cover-glass. Identified as *Gadus merlangus*.

FIG. 34.—Larva hatched from same kind of ovum on February 8th. Zeiss a_3, oc. 3, camera; no cover-glass.

FIG. 35.—Gadoid larva hatched from ovum, taken in tow-net January 20th. Probably *Gadus luscus*.

FIG. 36.—Ovum tken in tow-net January 28th; 8-cell stage.

FIG. 37.—Larva hatched from ovum of same species, collected January 30th. Hatched and drawn, February 2nd, without cover-glass.

FIG. 38.—Young Motella, 17 mm. long, from tow-net, May 31st. Drawn without the microscope.

FIG. 39.—Outline sketch of *Arnoglossus laterna*. Natural size. February 9th.

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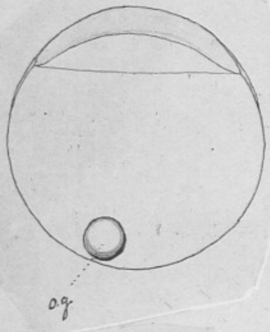

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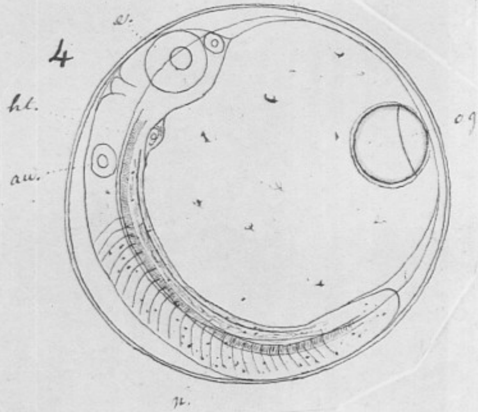

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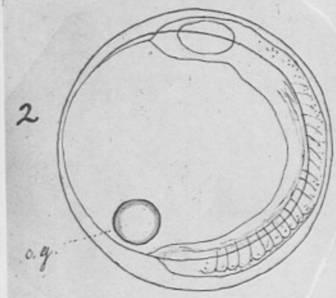

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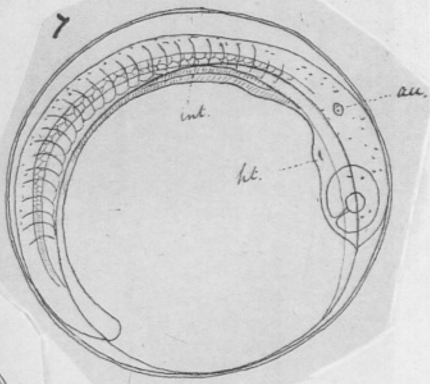

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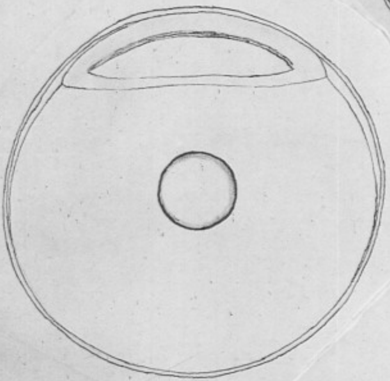

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G. C. Bourne del. *Glyptographie Silvestre et C^ie, Paris.*

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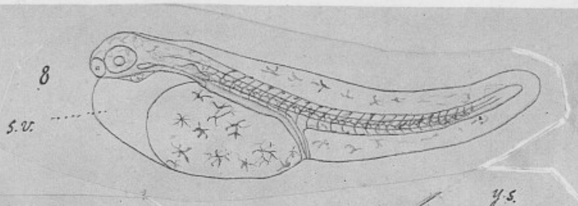

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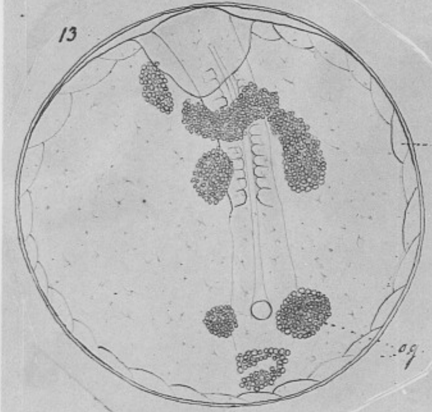

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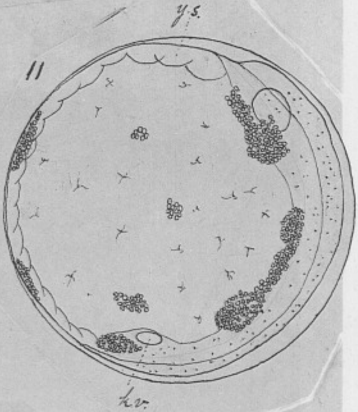

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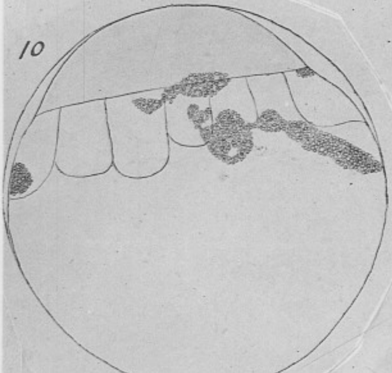

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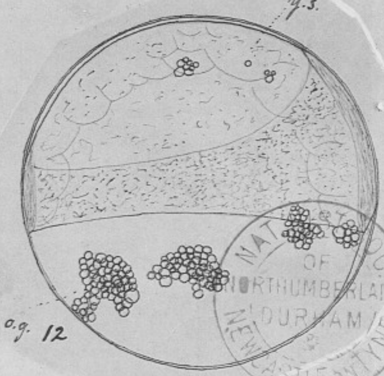

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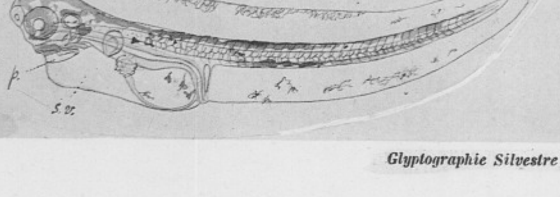

G. C. Bourne del.

Glyptographie Silvestre et C^ie^, Paris.

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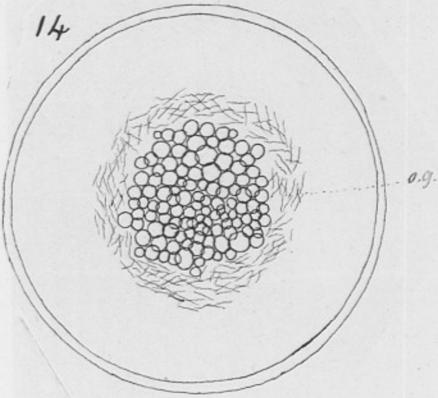

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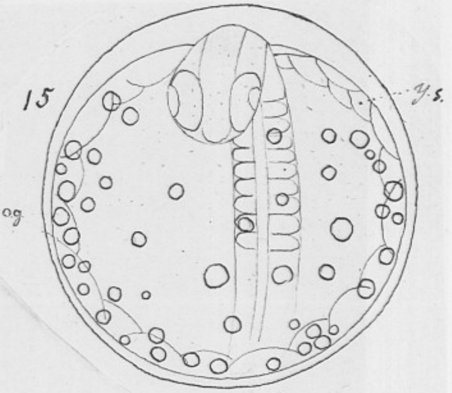

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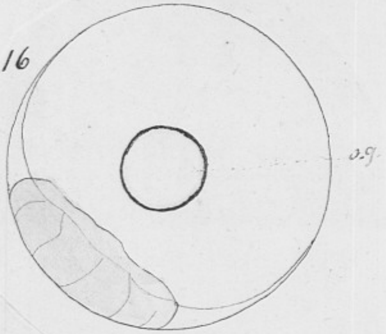

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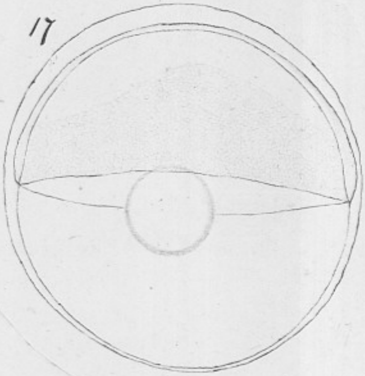

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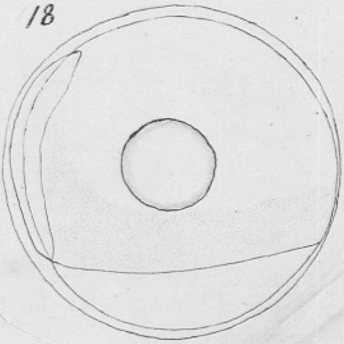

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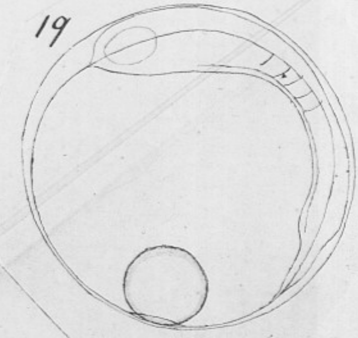

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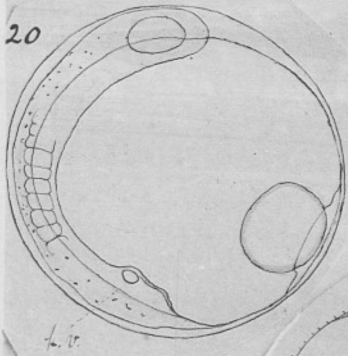

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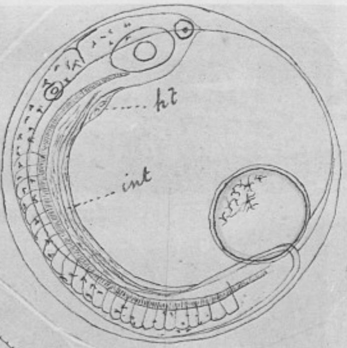

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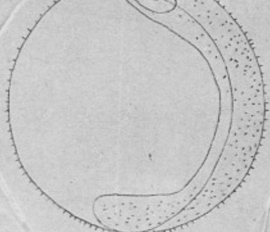

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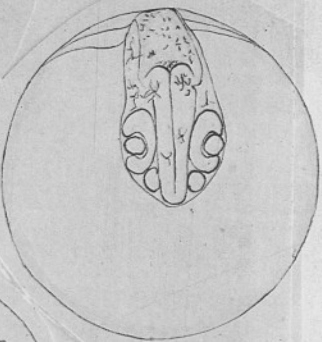

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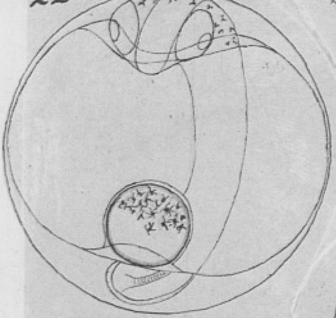

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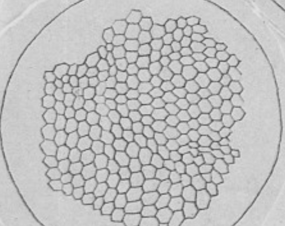

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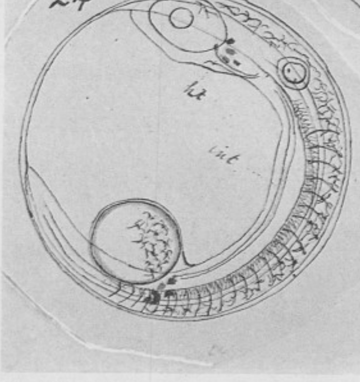

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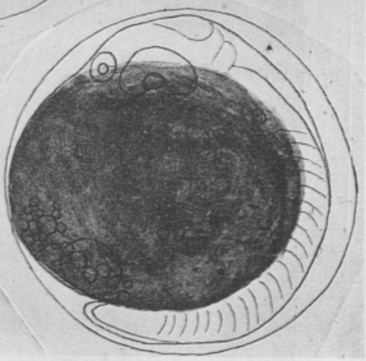

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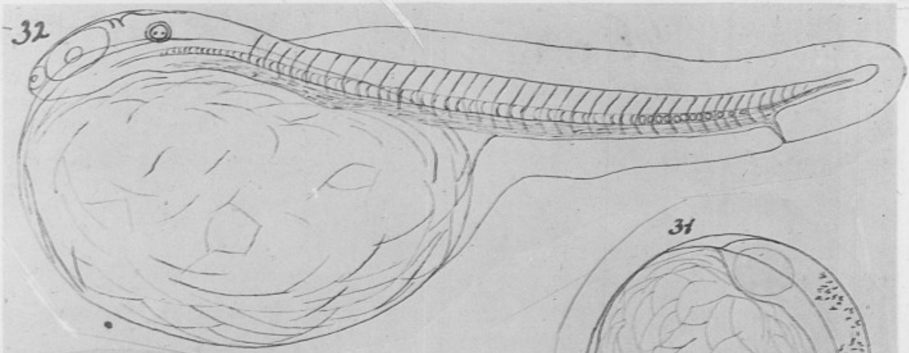

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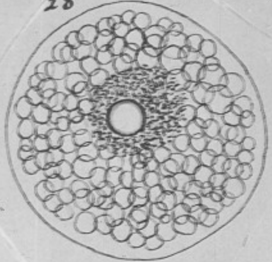

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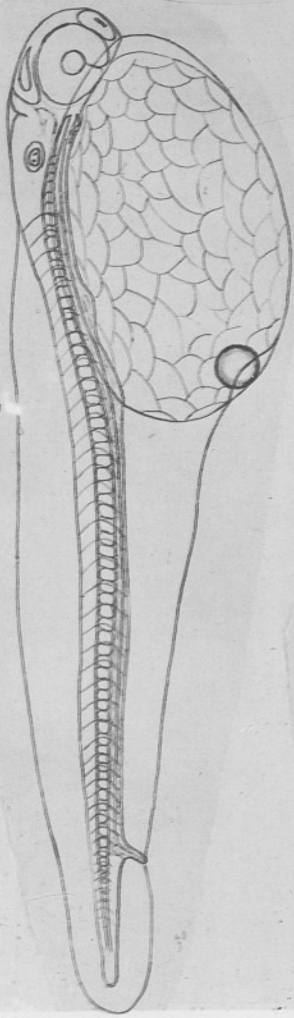

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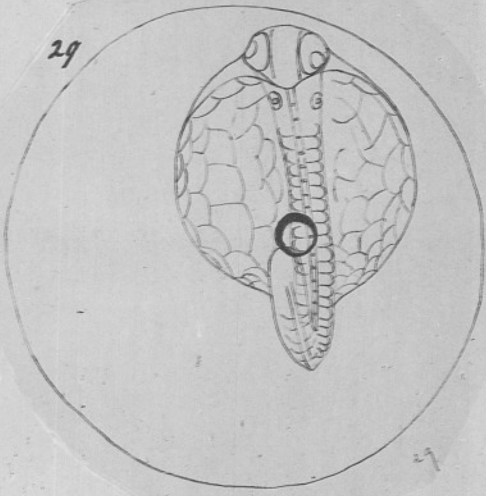

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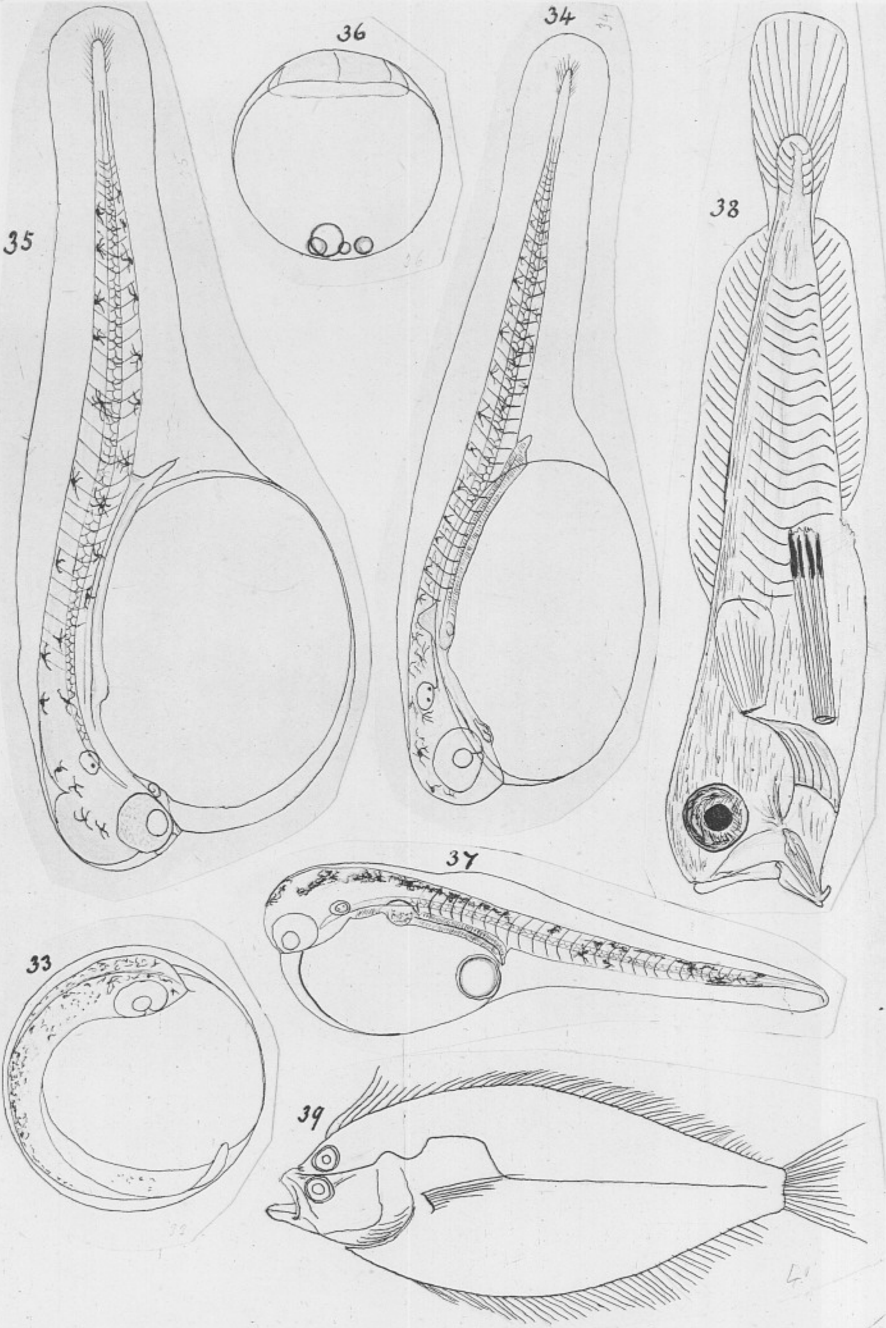

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