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Educator, Mentor

Woods Hole
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Institution

Daniel Merriman
1948.

THE LIFE-HISTORIES OF THE BRITISH MARINE FOOD-FISHES.

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NEST OF FIFTEEN-SPINED STICKLEBACK,
Castle Rocks, St Andrews.
5th June, 1885.
(Reduced.)

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F Huth Lithr Edinr

THE LIFE-HISTORIES OF THE BRITISH MARINE FOOD-FISHES

BY

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TO

THE MEMORY OF

GEORGE WILLIAM, 13TH EARL OF DALHOUSIE,

CHAIRMAN OF THE ROYAL COMMISSION ON TRAWLING, 1883–85,

AND SUBSEQUENTLY SECRETARY FOR SCOTLAND,

A NOBLEMAN DISTINGUISHED NO LESS FOR

HIS INTEREST IN THE WELFARE OF THE FISHING POPULATION

THAN FOR HIS SYMPATHY WITH

THE SCIENTIFIC INVESTIGATION OF THE FISHERIES,

THIS WORK IS DEDICATED

BY THE AUTHORS.

PREFACE.

IN presenting this little volume to our readers we do not primarily lay claim to any special elucidation of new facts, but it has rather been our intention that it should constitute a popularised epitome of the results achieved by British and foreign scientific workers at the St Andrews Marine Laboratory and elsewhere. These results, hitherto, have been from their strictly technical nature and method of publication inaccessible to many to whom the facts themselves would be fraught with interest. At the same time we may remark that, in dealing with each species of fish we have in many cases been enabled to add, by a careful examination of the type-collection and the fresh forms at St Andrews, important links in their life-histories which till now have escaped observation. We hope that this may enhance the value of the publication, especially to scientific workers in this field of research.

As far as has been possible we have, by means of footnotes, acknowledged the authorities from whom we have quoted or have derived our information, and we have not hesitated, both in the text and figures, to avail ourselves of the published contributions of our fellow-workers at home and abroad. From no work have we quoted more largely than from McIntosh and Prince's *Researches,* which may be said to have attempted for Teleosteans what the lamented Frank Maitland Balfour did for Elasmobranchs.

As regards our respective shares in the preparation of this book, we may state that the Introduction and Chap. I are the result of our conjoint labours, and that, whilst the senior author is responsible for the Chapters dealing with the Life-history and development of a fish from a pelagic egg (Chaps. II and IV), upon Pelagic Fauna (Chap. III), and the typical development of a Teleostean Fish (Chap. V),—the Chapter on the Rate of Growth of Fishes (Chap. VI) is the work of the junior. The composition of the special life-histories of each species was originally divided between us, the latter taking in hand those of the grey gurnard, dragonet, angler-fish, wolf-fish, viviparous blenny, mackerel, fifteen-spined stickleback, cod, haddock, whiting, poor cod, green cod, the rocklings, ling, hake, the sand-eels, plaice, dab, flounder, herring, sprat, pilchard, eel, and conger, the former of us undertaking the remainder. To this we should add that certain remarks were later made to such an extent in the parts dealing with e.g. the dragonet, viviparous blenny, cod, haddock, whiting and rocklings, that they must be regarded as a conjoint production.

While this work is only a step in a department to which future investigators will continually add, it is not without some satisfaction that one of us contrasts the condition of to-day with what it was when he undertook the Trawling work towards the end of 1883. Then the life-history of not a single British marine food-fish was known, at least from observations in our country. In the present work between 80 and 90 species are dealt with, the majority of the important forms more or less exhaustively. The larger share of this work has fallen to the St Andrews (now the Gatty) Marine Laboratory, and amongst those who have given their energies to this task E. E. Prince, R. Scharff, J. Cleland, J. Burdon Sanderson, F. Gotch, Marcus Gunn, E. W. L. Holt, W. L. Calderwood, W. E. Collinge, G. Sandeman, H. C. Williamson, J. R. Tosh, J. H. Fullarton, H. M. Kyle, W. Wallace, G. Lawrence, and J. L. Steven deserve acknowledgment.

For many interesting papers connected with the Fisheries we have to thank our fellow-workers in the maritime states of the Continent, in America, and the British Colonies. Such have been and will be of great value in these investigations.

In conclusion, we must express our obligations to the Council of the Royal Institution for the use of the woodcuts illustrating the life-history of a Marine Fish; to Prof. E. E. Prince, Dominion Commissioner in Fisheries, Canada, for drawings illustrative of the development of a fish in Chap. V; to the Fishery Board for Scotland for many acts of courtesy in these investigations; to Dr Fulton, their Scientific Superintendent, for his uniform zeal and energy in promoting the increase of knowledge in his department, and to Mr H. C. Williamson for much information from Italy and Germany.

W. C. M.
A. T. M.

GATTY MARINE LABORATORY,
April, 1897.

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INTRODUCTION.

WHEN we take into consideration the very important place which the marine food-fishes occupy in the general food-supply of the country it is remarkable to find how very little is really known, even by scientific men, of the life-history of the various species so familiar to every housewife. Few there are who could not readily distinguish such common forms as the cod, the haddock, the plaice or the sole when either or all of these were before them, but how many know anything whatever of the habits or the past history of these denizens of the deep? True it is that a cod is a cod, and a knowledge of its young stages and their food does not in any measure add to the intrinsic value of the fish as an article of diet; in fact we may go further and say that perhaps—in the case of some fishes—ignorance regarding their habits and food were better, lest their ready sale be affected thereby. We shall see, later, instances of fishes which are of so grotesque or repulsive an appearance that they must often of necessity have their form disguised or their heads and skins removed before being sent into the market lest their mere ugliness should seriously militate against their sale to an unreasoning and easily influenced public.

Be that as it may, we find in every other case in which man makes use of the lower animals for his own sustenance a wonderful amount of intelligent observation and study of the laws governing the existence and prosperity of these animals has been brought to bear upon them from the very earliest times of man's existence.

We may say with perfect justice that the fishing industry has been conducted by man, until recent times, in a manner which is at the same stage of evolution as that reached in the adaptation of cattle to his use when the primitive man hunted and slew in the chase just the few oxen he might from time to time require, quite regardless of the laws governing the existence and increase of the victims. Now however we find that cattle and sheep are carefully bred, fed and tended with one sole object in view, namely, the production of a maximum in quantity and quality of nourishing food, with a minimum expenditure.

To attain this end a large proportion of the human race spend their ceaseless energies upon the breeding, rearing and fattening of the animals which serve for the food of themselves and of their fellow-creatures.

The same remarks apply to the other large food industries, always excepting that of marine fishes. In this case we have only the mere capture, and neither time nor thought is expended upon the breeding or rearing of the finny tribe. There are obvious reasons for this state of things—when we come to consider the vast extent of the watery area dealt with and also the inaccessibility of the ocean-beds to the would-be investigator; in fact so great have these impediments been to the seekers after knowledge in all generations that the majority of the common inhabitants of the sea have clinging round the story of their birth and habits a long train of strange fables and weird anecdotes. What more extraordinary and grotesque inventions could one desire than the common but now historical notions regarding the life-history of the barnacle, or the habits of the pearly nautilus? Similar remarks apply to the quaint fables which are prevalent amongst those who are continually in contact with, and derive their livelihood from the capture of, the food-fishes surrounding our shores.

So great have these obstacles been that only in the last few decades have there been any really successful attempts to elucidate the history of the egg of the fish after its deposition by the female.

It is evident that before attempting to bring the fishing industry in any way into line with other industries, a thorough knowledge of the life-history, food, habits and diseases of the food-fishes is essential. With this aim in view scientists continue to accumulate facts relating to these, and although to the ordinary observer some of these facts may appear to be of no economic importance, as not directly bearing upon the points at issue, those more familiar with the progress of knowledge are aware that at any time some discovery seemingly insignificant in itself may throw a flood of light upon certain phenomena in a way which may directly benefit the progress of the whole industry.

Historical Remarks. It is, as already indicated, little more than a decade since the eggs and larval stages of almost all our British food-fishes were unknown—at least so far as regards their study by men of science in this country. For the discovery of the fact that the eggs of the cod, haddock and gurnard are pelagic, that is, float freely in the ocean, we are consequently indebted to Prof. G. O. Sars of Christiania, an able naturalist—trained from boyhood under a distinguished father, and who by a fortunate appointment to a fishery post in Norway was enabled to make these and other important observations from 1864 onwards.

Prof. Sars had gone in January of the year just mentioned to examine the cod-fisheries of the Lofoten Islands, and had watched enormous numbers of the fishes which come in to spawn. Toward the end of February he observed the earliest spawning. "By fishing with a fine net[1] on the surface of the sea I caught some small, completely transparent globules, floating on the water, which I at first took for some very low species of aquatic animals, as I was entirely ignorant of the peculiar spawning-process of the codfish, to which I shall now refer. I had in former times heard fishermen say that the roe of the codfish could be seen floating in the water, and that at certain seasons it filled the sea to such an extent as to make the water appear quite thick; but as this was in direct opposition to anything I had hitherto known of the spawning of fish, I could not but suppose that what had been taken for spawn

[1] Quoted from *U.S. Fish Commis. Rept.* (for 1877), 1879.

was in reality nothing but those lower aquatic animals which (as is well known) often fill the sea...Gradually these eggs, floating about freely, became more numerous, until, about the end of March, they filled the sea...I now succeeded in following their development step by step until the tender little fish slipped out of the shell and swam about in the water."

On a calm day on one occasion he found the surface of the sea covered with a dense layer of floating spawn, so that with a sufficiently large net he could have taken tons of it. This occurred over a celebrated fishing-ground, on which the cod were present in enormous numbers, so as to form what the fishermen called a "fish-mountain," the sounding lead or sinker in going down striking them as it passed. He also noticed that the spawning of the cod did not take place all at once, but thought it lasted several days. He also observed that the female fishes were nearer the surface than the males—both eggs and milt rising towards the surface. The haddock was noticed to have similar eggs. In 1866 and 1867 he followed the further growth of the larval cod to the post-larval stage of 7—8 mm. with their large broad heads and protruding eyes, while their tails vibrated like a fine thread in the surface-water as they fed on the very minute crustaceans. In June again, in the sounds and inlets inshore, he found a larger stage up to 24 mm. in incredible numbers snapping at the myriads of small crustaceans just mentioned, and which are generally known under the name of herring-food. He failed for some time to get the later stages, but at last he met them and the young haddock sheltering under the discs of the jelly-fishes, for the purpose of feeding on the small crustaceans that are parasitic on them or that become entangled in their envenomed tentacles. His largest form had now reached the length of 40 mm., a little more than 1½ in. Next season he procured in August older forms of 50 to 60 mm., near lines of floating sea-weed and *débris*, and pointed out how the dark cross-streaks he noticed in the younger forms of the previous year had now dissolved into three or four parallel lines of square spots of a more or less bright reddish-brown colour, which contrasted beautifully with the light hue of the body, resembling, indeed, a chess-board in the regularity of their arrangement. The sides and the head had an alternating silvery and golden gloss. The thread-like "beard" under the chin was now present, and the aspect was truly cod-like. They also occurred abundantly at the margin of the rocky shores and quiet bays, where they were better protected from the voracious pollack which decimated them in the open water. Their average size inshore remained till far into September from 60 to 70 mm., and this apparently stationary condition was explained by Prof. Sars as due to constant emigration and immigration of the swarms of young cod. The larger forms sought the deeper water, the smaller the inshore water.

Nor was the backward condition of British information on this head to be wondered at. The authorities entrusted with the patronage of posts in which marine zoology could be studied as a rule and with a singular impartiality filled them with those accustomed to other departments of the subject, while men imbued with enthusiasm for marine zoology were stationed far inland. Marine investigations, therefore, were often made under disadvantageous circumstances, or altogether ignored. Moreover, it is only within comparatively recent years that young observers could be trained in marine zoology with any prospect of future advancement, and even now the condition in this respect is far from satisfactory. It is no marvel therefore that progress in this country in regard to the life-histories of the food-fishes was more or less in abeyance.

Trawling Commission of 1883–84. When, in 1883, the Government of this country, in consequence of urgent complaints made by the line fishermen against the practice of beam-trawling, which, long pursued in English waters, had now made considerable progress in Scottish seas, appointed a Royal Commission to inquire into the subject, it was soon found that there were no well-ascertained facts with which to meet the great variety of statements brought forward on all sides. It became necessary, therefore, to undertake a series of scientific investigations in connection with the marine fisheries, and, amongst other points, the eggs, larval stages, young and adolescent conditions of the food-fishes received special attention.

At this time, indeed, the observations of Prof. G. O. Sars were little known in this country, the floating or sinking of the eggs of such fishes being vaguely associated with the temperature of the water. Yet Sars had shown at the International Fisheries Exhibition in London this year (1883) a series of drawings illustrative of the development of the cod, and the Americans had for some years been experimenting in the artificial hatching of the same species.

Fishermen's views. At this time the almost unanimous opinion of British fishermen, and not a few others, was that the common food-fishes sought the shallow water of the bays and inshore grounds for the purpose of depositing their eggs on the bottom, for demersal eggs were alone known to them. There is no doubt that the masses of the eggs of the lump-sucker and sea-scorpion (*Cottus*) had been in some instances mistaken for those of the haddock, and, so great was the interest, even ingeniously hatched to prove it. Nor were British fishermen alone in this idea. The late Prof. Spencer Baird, the originator and first Chief of the American Fish-Commission, found the same condition on the other side of the Atlantic. The fishermen had not the slightest idea of this floating property, but thought that the female food-fishes deposited their eggs on the rocks, where they were fertilised by the males. They had indeed noticed the little transparent bodies in the water, but it never occurred to them that they were the eggs of any fish. In this respect, therefore, as already stated, they were considerably behind the Norwegian fishermen, who pointed out the pelagic eggs to Prof. G. O. Sars. Yet it was only necessary to examine the more or less ripe "roes" of such fishes as the cod as they were thrown, for instance, amongst the offal on the pier at Anstruther to satisfy even the most cautious on the subject, and more especially by placing the mature eggs in a pail of sea-water. Literally this was the mode by which the late Lord Dalhousie, chairman of the Royal Commission above alluded to, first became acquainted with such pelagic eggs—while waiting at Anstruther for the ship which then carried him seawards—where multitudes of similar eggs, mingled with the larval fishes from a few hours to a few days old, filled the tow-nets.

Yet though this was the condition of the information on the subject in our country, the labours of the American Fish Commission and Prof. Alex. Agassiz had shown that besides the cod, haddock and gurnard the majority of the American flounders, certain kinds of wrasses, a species of sparling, shad, mackerel, Spanish mackerel, a kind of dory and the frog-fish were amongst those which had floating eggs. The late Dr Malm of Gothenburg further increased the list by discovering that the eggs of the plaice were similarly buoyant; and the late able worker, G. Brook, added to this category the eggs of the lesser weever and the rockling.

When the Trawling Report was issued considerable disappointment was evinced by those who firmly believed in the supposition that the eggs of all the food-fishes were deposited on the bottom, and thus were destroyed by the trawl. Much of this, however, was due to other influences than those which arose on the part of the fishermen themselves, a feature as prominent and far-reaching to-day as in 1884. Those fishermen, however, in contact with the Marine Laboratory at St Andrews, and especially those who saw the work amongst the pelagic eggs then being pursued by the earnest and genial Prof. E. E. Prince[1], and observed the manipulations of the attendant who went amongst them and removed from the dead fishes the ripe eggs and milt, placed them in sea-water and showed them how the former floated as minute spheres of glassy transparency, soon altered their opinions. Many of them were by and by provided with earthenware jars which they took to sea, and in some instances were successful in bringing to the laboratory fertilized and floating eggs of forms not yet examined. Thus a change was speedily brought about without much notice, so that in July of the same year (1885) when, with Prof. Ray Lankester, at Oxford, urging the University to support the scheme for the proposed Marine Biological Laboratory at Plymouth, one of us was able to adduce this fact as an instance of the effect of such institutions even on the opinions of the fishing population.

[1] Now Commissioner of Fisheries in Canada.

Floating or Pelagic Eggs. During the investigations connected with the Royal Commission on Trawling ample opportunities were afforded for becoming acquainted with the pelagic eggs of sea-fishes. They were found to frequent the surface, mid-water and bottom, and their abundance in a given area was generally diagnostic of the prevalence of the parent fishes. The latter feature was boldly illustrated by contrasting in April the area at Smith Bank, where the eggs were in enormous numbers, with that off the Forth, where they were fewer. In the former area the vast multitudes caused the sea to resemble a great hatching-pond in which eggs and larval fishes occasionally were driven by surface-currents into long lines marked at a distance by numerous ducks and other sea-birds that greedily fed on them. It often happens that when one region of the sea is almost devoid of pelagic eggs, for example the surface, they may be found in mid-water or near the bottom. Thus the investigations with the trawl-like tow-net show that a vast number of pelagic eggs, such as those of the cod, whiting, rockling, sole, flounder, gurnard, sprat and other forms, are to be found near the bottom, when the surface and mid-water nets are devoid of them. The cause of this feature is not fully known, but it may, as in the case of pelagic invertebrates, be due either to temperature or to currents. The areas usually called fishing-banks especially abound in these pelagic eggs during the spawning season, and thus in a sense the examination of the tow-nets gives certain data in regard to the prevalence of the food-fishes. Pelagic ova, however, may be borne long distances before hatching takes place, and the larvæ may subsequently be still further carried from the spawning ground, so that their distribution is amply provided for. Thus it happens that the inshore grounds receive supplies of eggs from the offshore, where many of the breeding fishes are, and on the other hand the young and adolescent fishes leave the inshore and seek the deeper waters beyond.

To close the inshore grounds therefore (except to the liners) and leave the offshore free to all may not have the result of increasing the food-fishes of the area to a noteworthy extent, since the spawning fishes which supply a constant increment from the offshore are decimated and scattered, and the recuperation of the inshore is interfered with.

One of us[1] has pointed out the necessity for caution in drawing deductions from the experiments hitherto conducted by the Fishery Board in Scottish waters. The great increase in the number of fishes caught by the 'Garland' in St Andrews Bay and elsewhere in the second year of the work, caused the Board to extend the closed areas, and further to close a large portion of the Moray Firth. Yet next year the numbers captured in St Andrews Bay by the 'Garland' fell greatly, and still more so in 1889, again rising in 1890, but falling in 1891 only a little above what they were at the commencement of the experiments in 1886. No safe deduction therefore was possible under the circumstances, and since the number of the larger fishes seemed in no way to increase otherwise than the special opportunities for capture explained, such action was probably the result of other data than those supplied by science. The whole subject will shortly receive treatment by one of us, so that it is unnecessary to go into detail at present.

Examination of Areas. Since the period of the Trawling Commission more or less systematic examination of the various areas closed to trawlers has been carried out by the Fishery Board for Scotland by aid of the steam-ship 'Garland,' and constant examination of St Andrews Bay by the boats connected with the Marine Laboratory has given us more precise knowledge concerning pelagic eggs, larval and young fishes and their surroundings. In many instances the eggs and larvæ have been examined in the living condition, while in the others careful preparation has enabled us to obtain a fair knowledge of species, and also to estimate their numbers. As a rule the eggs of each species have certain characters peculiar to them, whether in regard to size or structure, and thus their prevalence in a given area and at a given time may approximately be ascertained. The characteristic appearance of the egg of the sole, for instance, at once indicates the presence of the adult in the neighbourhood, and the introduction of a larger number of

[1] *A Brief Sketch of the Scottish Fisheries chiefly in their Scientific Aspects.* By Prof. McIntosh, 1892.

adults into a particular area is followed by an increase in the numbers of such eggs, as illustrated recently in St Andrews Bay, where about five hundred soles of various sizes were transferred from English waters[1].

In the subsequent pages are set forth the leading facts concerning the life-history of our more common food-fishes, the more exclusively scientific terms being as far as possible avoided in their narration.

[1] The kind co-operation of J. W. Woodall, Esq., M.A., of St Nicholas House, Scarborough, deserves cordial acknowledgment.

CHAPTER I.

GENERAL REMARKS ON THE EGGS OF MARINE FISHES.

Groups of Food-fishes. The British food-fishes fall naturally under two groups (excluding the lamprey and the hagfish, not treated of in this work), the first, that of the cartilaginous fishes, the sharks, skates and dog-fishes, and the second, that of the bony fishes, comprising all the remainder, and whose life-histories form the special subject of this work.

The former differ mostly from the latter in having a soft cartilaginous skeleton throughout life, in having the gill-slits separate from one another and not covered by a shield or operculum, and in other points of anatomy, into which we need not enter here; but the great difference which concerns us is that of development. The cartilaginous fishes have a very few, very large eggs, often protected in a hard chitinous skin which is popularly known as a "sea-purse" or "mermaid's purse." This is usually laid by the parent either on sand or in the vicinity of sea-weeds, amongst which the dark olive colour of the "purse" serves to hide it, or again in other cases the long filaments at the end are attached to various foreign bodies. Most cartilaginous fishes carry the system of "protection" still further and the whole egg is carried about inside the parent's body till the embryo is at a sufficiently advanced stage to take care of itself, when it emerges from its parental covering and commences its individual existence; this is termed a viviparous form of development.

On turning to the bony fishes, such as the cod or the herring, we are at once struck by a great contrast between their development and that of the cartilaginous fishes.

The egg of the cod is very small, and is surrounded by a delicate capsule or membrane. The main part of its contents consists of a mass of nutritious yolk, ready-prepared by the parent for the use of the little embryo, and as the egg is entirely left to shift for itself, the numbers destroyed by voracious enemies, and still more by adverse physical conditions[1], must be very great indeed. Hence, in order to maintain the normal number of the species, the cod lays an enormous number of eggs, one female laying several millions. The same carelessness as regards its young is exemplified by these fishes beyond the egg-stage. The young cod escapes from its egg at a much earlier stage of development than the young skate, and is hence in a much more helpless condition, larval cod being at first unable to look after themselves, and at this stage also the mortality of the little fishes must be very high. In this respect the cod is an extreme type of the bony fishes, and in such a very large group of animals there are endless variations both in the character of eggs and in the mode of development.

General Remarks on Eggs. In general form the eggs of the ordinary food-fishes[2] are circular. On deposition they are usually invested by a single layer (capsule or *zona radiata*). But some are ovoid or fusiform, as in the case of the anchovy and goby, and others have long filaments attached to the capsule, as in the gar-pike, saury-pike, flying-fish and sparling, these filaments occasionally fixing them to foreign structures. Amongst other interesting types are the large eggs of the stickleback, the wolf-fish and the salmon-tribe. These eggs, however, are surpassed in size by those of the Siluroid genus *Arius,* found both in the Old World and the New (Ceylon and Guiana), the eggs of which are somewhat larger than a pea (viz. 5 to 10 mm.). This is not the only remarkable feature in these fishes, for as Drs Günther and Wyman and Prof. Sir William

[1] "Effect of pelagic spawning habit upon life-histories of food-fishes." *Report Brit. Assoc.* 1896. A. T. Masterman.

[2] Vide Prof. McIntosh, *Nature*, April 9, 1885, Vol. 31, pp. 534 and 555.

Turner have shown, the large eggs are carried without injury by the male in his mouth and gill-chamber until hatched, the small and almost granular palatine teeth making this possible. He thus acts the part of a dry nurse, as also does the male pipe-fish and the sea-horse, the eggs being borne by the male in a pouch on the under surface, the young fishes after hatching even returning when alarmed to the pouch for safety. In another Siluroid (*Aspredo*) from Guiana the remarkable exception occurs of a female fish interesting herself in the care of the young. At the breeding season the skin on the under surface becomes soft and spongy, and the eggs, which are deposited on the ground, adhere by simple pressure of the body over them, somewhat after the manner observed in the Surinam toad. An Indian Lophobranch (*Solenostoma*) shares the distinction just mentioned, in which the pelvic (ventral) fins—free in the males—coalesce to form, with the integuments, a pouch for the reception and hatching of the eggs. These and other examples, such as the stickleback and the viviparous blenny, form a series of types in which the amount of protection given to the future generation by the parent approaches that shown in the viviparous cartilaginous fishes.

Viviparous Fishes. Too little is known of the life-histories of the viviparous fishes to enable us to generalise with safety, but this much is evident that the young fishes on extrusion are in some cases of a very large size proportionally, as in the viviparous blenny, where they measure 2 inches, but they are comparatively few in number. This widely distributed species, however, has held its own in the struggle for existence, but it nowhere occurs in profusion. The same remarks apply to the viviparous "Norway haddock" of our northern waters. Nowhere are these viviparous fishes so abundant as on the western coast of America, where Prof. Carl Eigenmann, who has recently made a careful study of their development[1], found them forming no less than 30 per cent. of the bony fishes at San Diego. They belong to two families (*Embiotocidae* and *Scorpænidae*), the former including fishes frequenting the in-

[1] "On the Viviparous Fishes of the Pacific Coast of North America," *Bull, U. S. F. C.* 1892.

shore waters, the latter the deeper water, as in our own country (viviparous "Norway haddock"). The large number of species in each family showing this condition on the west coast of America would point to it as the most favourable for their survival. It is probable that this habit was slowly acquired, those having the tendency best marked being enabled to leave a larger number of young, so that their chances of continuing the race were greater.

Divisions of Eggs of Food-fishes. The eggs of the bony food-fishes (*Teleosteans*) may conveniently be divided into two great divisions in accordance with their structure and environment, viz. (1) those which are deposited on the ground, usually called demersal, and (2) those which float about in the water, and are termed pelagic. In the former group, viz. that of the demersal ova, only the herring, the sand-eel, and the wolf-fish (catfish) are conspicuous, while the large majority of the food-fishes have pelagic eggs; such as all the cod-tribe, flounders and gurnards. No very evident connection exists between the habits of fishes and the condition of the eggs. Thus the pelagic herring—one of the most prolific of marine fishes, and one still as abundant as ever, notwithstanding the enormous efforts of man to compass its destruction—has a demersal egg, deposited in masses on the bottom, while its congeners the sprat and the pilchard have pelagic eggs. The ground-loving frog-fish has pelagic eggs, but the wolf-fish which likewise haunts the bottom has large demersal eggs. The wandering cod-tribe and the race of sand and mud-loving flounders have each buoyant pelagic eggs, which rise to the surface of still sea-water in a vessel like globules of oil. It would indeed be a difficult task to predicate from the habits of a fish the nature of its eggs, since forms frequenting the same region, such as the sand-eel, armed bullhead, weever and dragonet, have eggs totally different in nature, the eggs of the two former being demersal, while those of the latter are pelagic.

Pelagic and Demersal Eggs. But whatever may be the cause of this essential difference in the eggs of the marine fishes, and more especially the food-fishes, there can be little question that the pelagic character leads to the dispersion of the species throughout the ocean, tends to minimise the destruction of the eggs by any special agency, and appears to have played an important part in the preservation of the various food-fishes. Little explanation of the first proposition is necessary, for it can readily be understood how oceanic currents and tidal changes carry the buoyant ova far and near, peopling regions unknown to the adults and spreading such species as the cod throughout the North Sea and both sides of the Atlantic, and this altogether irrespective of the swimming powers of the larval, post-larval, adolescent and adult fishes. In the case of those fishes which inhabit the bottom and the range of which in many cases is therefore restricted, the pelagic eggs and young carry the species widely throughout the ocean—a provision so conspicuously observed in fixed invertebrates, the larval forms of which often have remarkable swimming powers. The second proposition, that the pelagic eggs escape wholesale destruction by special agencies, will be understood if the almost invisible glassy spheres drifting in every direction are contrasted with the masses of the ova of the herring deposited on the bottom, and which form the food of hordes of haddocks, cod and green cod (saithe) following in the wake of the spawning fishes, the cod for instance greedily gulping the gravel to which the eggs adhere in its eagerness to secure them. As many as eighty boxes of large haddocks have been trawled[1], every one of which had its stomach distended with the eggs of the herring, and this is but an indication of the enormous loss sustained twice a year in the life-history of this species. A similar contrast may be made between the eggs of two rock-loving fishes, viz. the lump-sucker and the rockling. The former deposits its eggs in masses attached to ledges of rocks and stones, and they are often laid bare by the tide, so that besides the depredations of whelks and other forms in the water they are devoured by crows, starlings, and in some cases even by rats when exposed at ebb-tide, notwithstanding the faithful guardianship of the male. The latter has pelagic eggs that are widely disseminated through the water.

It is true that occasionally pelagic eggs when occurring in

[1] By Messrs Joseph Johnston and Sons, Montrose.

enormous quantities, as G. O. Sars, for instance, describes off Lofoten, may be beached by the tide, but such has never been observed in our country, probably because the fishes are fewer and the spawning-areas at a greater distance from the shore. Again, these small glassy spheres are often engulphed by such pelagic fishes as the herring, when swallowing their crustacean prey, as many as twenty having been observed in good condition in the stomach of a single example. They may also be destroyed by the small crustaceans (shrimp-like forms) amongst which they float, as well as by other invertebrates which form the pelagic fauna usually so abundant in our waters.

The third and last proposition, viz. that the pelagic condition of the eggs appears to have played an important part in the preservation of the various food-fishes, offers many points for remark. In the first place, fishes which are endowed with this property do not shed all the eggs at once, but only a portion of the roe ripens at a given time and the eggs pass externally, and so at intervals until all the mature eggs are discharged. Several weeks would thus appear to elapse in certain cases before an individual ceases to spawn. The effect of this condition is twofold, viz. to give a much wider area for distribution and a series of gradations in the growth of the young of the same fish. In this way a succession of larval fishes is liberated, and time is afforded for those of one stage to disappear from the surface before those of the succeeding stage take their places. Moreover, it is evident that even if circumstances were unfavourable for the vitality of one series of such ova, they would rarely be unfavourable for all. Such eggs are therefore in a different category from those of the salmon and wolf-fish in which the contents of the ovaries ripen simultaneously and are discharged about the same time. On the whole, it would seem that the advantage is on the side of the minute translucent pelagic eggs, which under the varied circumstances of their periodic discharge seem to be placed in favourable conditions. Again, pelagic eggs as a rule are small, so that instead of the 28,000 or so of ova of the salmon, there are 6—9 million eggs in the cod, and a still larger number in the turbot.

An ample margin is thus provided for losses during the development of the embryo and the growth of the young. The pelagic condition of the eggs likewise gives the species a double means of dispersion, which is important when we consider the great areas of the North Sea and the Atlantic that are yet unexplored as regards their food-fishes. The capture of the adults on a large scale can only be carried on—as a rule—in comparatively moderate depths, the deeper waters thus forming a sanctuary, from which may issue eggs and young fishes for the recuperation of the areas which have been thinned.

One of us[1] has recently argued for the probability that the pelagic spawning condition is the more primitive, and that the demersal habit has been independently acquired in the later history of the various species which now spawn in that way. The following considerations amongst others were cited in favour of this view:—

The pelagic-spawning fishes exhibit a greater fecundity, they have a more extended period of ripening and deposition of eggs; they show no secondary sexual characters, and have promiscuous fertilization. The young in these fishes make the least demand upon their parents (i.e. if we may judge of demand by supply) for nutrition or protection, and are hatched at a much earlier stage of development. Lastly, it is amongst the species with pelagic spawning habit (e.g. the plaice) that the larval and post-larval migration is most marked, the demersal types forming a series (from herrings to small littoral forms) in which the early stages are as it were telescoped up and the migration thereby eliminated from the life-history.

The pelagic eggs are deposited by the parents in the water and there fertilized. They are very little lighter than sea water and hence rise slowly towards the surface of the ocean, when their development proceeds till the capsule is burst by the little larva, which then emerges from its confinement. These eggs are all beautifully translucent, a fact which combined with their small size no doubt saves an immense number of them from destruction, as their presence even in a small

[1] A. T. Masterman. Op. cit.

confined volume of water (e.g. in a small jar) is easily overlooked by the casual observer.

The appearance presented by a number of pelagic eggs floating in sea water, like tiny pellucid bubbles, is not easily forgotten, especially if they should happen to belong to one of the species (e.g. Gurnard) which have inside the egg a glistening little oil-globule which moves freely in the yolk.

Condition of pelagic eggs. Pelagic eggs usually float singly in the water, except in certain notable instances, e.g. the frog-fish, in which the eggs are surrounded by a transparent gelatinous substance having the form of a long riband, as first described by Prof. Alex. Agassiz. Prof. E. van Beneden also found some minute isolated and agglutinated floating eggs which he was not able to determine, and Prof. Haeckel procured similar eggs off the coast of Corsica[1]. Such eggs differ from the pelagic nests of the Sargasso sea, with their masses of fimbriated eggs as described by Louis and Alex. Agassiz, J. T. Cunningham, Möbius and others, and which belong to such fishes as *Antennarius* and *Pterophyrnoides,* near allies of the frog-fish.

A marked translucency, in many cases almost perfect transparency, of both capsule and contents usually indicates the healthy pelagic egg. When developing in the ovary such eggs are quite opaque, as observed in the "roe" on the fishmonger's slab, but towards maturity the granules of the yolk disappear and the ovarian egg becomes quite translucent.

From observations made by Mr Harold Dannevig at the Dunbar Fish Hatchery of the Fishery Board in 1884–5 the pelagic eggs of the plaice, lemon-dab and other forms would seem to be shed for the most part at night.

When placed in a vessel of sea water the eggs persistently float on its surface, descending but a very little when the jar is rudely shaken. Even after a protracted journey only the dead ones roll on the bottom of the vessel. All the floating eggs are living. For instance, eggs removed from the cod and fertilized on Smith Bank off Caithness, and even at a much greater distance, were carried to the Marine Laboratory at St Andrews, still

[1] Fierasfer?

floating, on arrival, at the surface of the water. On transferring the eggs of the cod to a larger jar and turning on a tap of sea water they in a few minutes went to the bottom, the impure sea water on these occasions proving speedily fatal. The addition of a small quantity of methylated spirit in the same way sends all the eggs and embryos to the bottom. Sars, indeed, mentions that if the eggs of the cod are placed in fresh water they sink and never again rise. They are killed—just as a newly hatched salmon is killed, though somewhat more slowly, by immersion in sea water. Sars thinks that even a fall of rain might affect the floating of the eggs in the sea, but this is unlikely, since as a rule the eggs are not, in our seas at least, found quite at the surface. Occasionally the diminished density of shore water suffices to send the eggs captured in the open sea to the bottom of a vessel, but they are by no means killed. The attachment of fine particles of mud and sand in the same way carries the eggs downward, and often proves disastrous to them.

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

While thus, if care be exercised, there is no great difficulty in transmitting the pelagic eggs[1] of marine fishes great distances immediately after fertilization, it is, in critical cases, better to wait till the embryo is outlined before subjecting them to such vicissitudes. The mortality is by this method

[1] In stoneware jars tied over with cheese-cloth, and comparatively few eggs in each vessel.

greatly reduced, and eggs can be transmitted, for instance, from Shetland to St Andrews with comparatively slight loss. Even though kept for ten days without renewal of the sea water, and the eggs hatch on the way, the lively little cod, with their characteristic black pigment-bars, swim actively near the surface of the water, darting hither and thither when interfered with, while a stratum of the dead lies on the bottom. The water may even be somewhat milky and the odour perceptible, and yet the larvæ survive—until, as Sars also found, the yolk-sac, which supplies them with nourishment, is absorbed.

Throughout the spring and summer countless hosts of these little eggs belonging to many species, varying slightly in size and structure, float about near the surface and in mid-water, tossed here and there by the waves and at the mercy of every tide or current. At certain spots off the coasts, at the meeting place of currents, these eggs accumulate in millions and may then be taken in any numbers by dragging fine tow-nets through the water. During the wanderings of these eggs the development of the embryo inside progresses slowly but surely, until through the transparent tissues the principal organs and shape of the future little fish can be clearly discerned, and soon after the lively movements of the same cause a rupture of the egg-membrane, which, no longer required, sinks to the bottom of the sea, leaving the helpless larval fish to toss about in the surface-water until it gradually gains size and strength to regulate its own movements and to hunt for the minute crustacean organisms upon which it feeds.

Number of floating eggs diagnostic of number of breeding fishes. The condition of the fish-fauna of the various grounds may to some extent be estimated by the number of the eggs floating near the surface. It has been seen that Sars found the water crowded with a multitude of eggs off the Loffoden Islands, where enormous numbers of cod are captured. In our seas no fishing bank is so prolific, the greatest number of eggs occurring on Smith Bank, off Caithness, and the next on the rich grounds off the Island of May—both of which present a great contrast with the meagre supply of eggs of round fishes floating in St Andrews Bay. The proportional numbers in each case accorded fairly well with the captures of adult cod at that time (1884) in the several areas.

No sight can be more interesting to the naturalist than the surface of the sea, in the condition just mentioned, about the beginning of April. The rough water of the great fishing grounds, such as off Smith Bank, and somewhat further from land, is enlivened by large groups of gulls, guillemots and the ubiquitous gannets, apparently feeding on the smaller fishes which have been attracted to the surface by the wealth of food. At short intervals the long dorsal fin of a huge "killer" appears above the surface and the water behind it is churned into foam by the powerful strokes of its screw-like tail; while a small group of bottle-noses (another kind of toothed whale—the ca'ing whale of the Shetland Islands) is recognized by the noise and spray, as one or more leap like dolphins from the sides of a huge wave. The tow-nets collect large quantities of eggs and larval fishes which have just been hatched. They further show that innumerable minute crustaceans (Copepods &c.), multitudes of the young or nauplius-stage of sea-acorns and other forms, *Sagittæ* (arrow-like worms), and many peculiar annelids are present. It is evident, therefore, that the young fishes are placed in the midst of a rich surface-fauna, the more minute forms of which would readily serve as food as soon as the supply of yolk disappears and the mouth opens.

In the study of nature and nature's ways the naturalist is often brought face to face with truths bewildering in their remorseless fatality, but few chapters of animal development present one with such a history of ruthless destruction of the many and survival of the few as that presented here. A ripe female cod may at a low estimate be reckoned to give rise to 5,000,000 eggs (though in nature it is doubtful if all these are available), and as we have no reason to believe that the number of cod is appreciably increasing we may say with certainty that 4,999,998 of these, at some stage of their career from the egg to the mature adult, will meet with an untimely death at the hands of countless enemies. Facts such as these bring home the intensity of the struggle for existence going on around us even in so large and open an arena as that presented by the ocean. The struggle can be none the less keen though in this case the agencies of destruction are probably more of a physical than an organic nature. Before leaving this part of the subject it is well to note that the demand of the succeeding generation upon its parents is the same in each case:—for the cod, in return for the entire neglect of its young from the moment of oviposition, has to meet the enormous demands upon its organisation which are caused by the production and ripening of the huge number of eggs which are necessary to maintain the balance of nature, demands so great as to render the parent-fish almost unfit for food when in the spent condition.

This utilization of the tissues of the parent-fish during the growth of the roe is a subject that has recently attracted much attention in connection with the salmon, since it has been found that peculiar chemical changes take place in the muscles under these conditions. Dr Noel Paton, with the aid of Dr Gulland and others in Edinburgh, is at present engaged in an extensive inquiry of this nature on the salmon, a fish in which the changes have important legal as well as physiological bearings. We look forward to the publication of these observations and also those of Dr Alex. Brown, on the salmon of the Aberdeenshire rivers, with much interest.

We also find that the fishes with pelagic eggs have a larger proportion of the female sex, whilst the reverse is the case with fishes laying 'demersal' eggs. Thus female gurnards are found in the proportion of four to every single member of the opposite sex, whilst the male gurnard appears to be slightly smaller than the female. In the case of the haddock and whiting the proportion is that of one male to two females; while in the cod the number of each sex is much more equal, about four males occurring to every five females.

As regards the relative size of the different sexes, the whiting, like the gurnard and all flat fishes, has a larger female, whereas the male haddock and cod are slightly larger than the females.

In the 'pelagic' fishes not only are the females more abundant but the ovaries are much greater in bulk when compared to the milt than is the case in 'demersal' fishes. In the cases where there is not a great disproportion between the relative number of the sexes, as, for example, the cod, the disparity in the relative sizes of the organs is more marked, always to the disadvantage of the male sex.

Demersal eggs. In the fishes of 'demersal' habit the males are usually in excess of the females, which also probably results from the fact that the process of fertilization in these fishes is not assisted by physical factors, as in the 'pelagic' fishes. In the latter the micropyle or minute aperture of the egg is downwards, and the 'milt' being specifically lighter than the water passes upwards and meets the egg as it slowly ascends through the mid-water.

In the 'demersal' species the batches of eggs are close together and are not so readily accessible to the male element. In this category are most fresh water fishes (except the shad), the eggs being deposited on the bottom like those of the salmon, attached to foreign bodies like those of the sparling, or to water-plants as in the carp and the pike. These fresh water fishes are held to be descended from marine ancestors which had already acquired a demersal spawning habit. There are obviously many physical difficulties in the way of a fresh water fish reproducing itself by buoyant eggs. (See 'Flounder' and 'Eel.') Amongst the marine fishes demersal eggs occur—in the herring, wolf-fish, shanny, various suckers, gobies, armed bull-head, sea-scorpions (*Cotti*), ballan wrasse, fifteen-spined stickleback, gunnel and others.

These 'demersal' eggs are so called because they are deposited by the mother upon the bed of the ocean, and in many cases some amount of regard for concealment is shown in the selection of a site for the deposition of them. As we might expect, therefore, these eggs are not usually by any means so numerous and are not so translucent, but often have a typical colour and are opaque. They are usually deposited in masses of scores or hundreds attached to weeds, shells, or rocks, where the development takes place up to the hatching stage, often under the direct protection of the male, as in the case of the stickleback and lumpsucker. If, as already indicated, we separate the bony fishes into two divisions according to the character of their eggs (either pelagic or demersal) we at once note that this character by no means agrees with the characters of the adult fishes which determine their relationships; thus we note for example that the sprat has a typical pelagic egg, and its close ally the herring, so close that their young forms are hardly distinguishable, has a demersal egg, laid in clusters upon gravel, seaweeds and zoophytes. This and other instances point to the fact that the pelagic or demersal habit is not determined by the general structure of the adult but by other factors.

Quite the same absence of connection occurs between the size of pelagic eggs and that of the adult, the turbot for instance having a smaller egg than the plaice, and the cod than the whiting, although the greater size of the turbot and the cod when compared with the plaice and whiting must be familiar to all. On the other hand the size of the eggs seems in some measure to vary inversely as the number, as will be seen by comparing the cod and the whiting. Too much reliance however must not be placed upon this comparison.

Lastly, the oil-globule does not by any means characterise one particular group of fishes, the closest allies differing in this respect; the single instance of the turbot's egg with its oil-globule and that of the plaice with none must here suffice.

The study of the development of food-fishes furnishes one with beautiful examples of what is known as convergent evolution.

The most important demersal egg amongst the food-fishes is certainly that of the herring. This is attached so securely to the structures on the bottom or to the bottom itself that so far as experience goes it is never tossed on shore or brought up by the trawl in the ordinary course of work. The eggs have a firm capsule coated with an adhesive substance which fixes them firmly to each other and to foreign surfaces. The adults, which show a remarkable persistence in attaining their spawning grounds, take, like the salmon, no further heed of them after deposition and fertilization. In some cases, however, the eggs are tended by both or by one of the parents. The well-known case of the stickleback and its nest is an example in fresh water. The fifteen-spined stickleback, gunnel, bimaculated sucker, pipe-fishes, and lumpsucker are instances in the sea, the male in the majority acting as the guardian.

Whether the eggs of the wolf-fish (cat-fish) are at first fixed to the bottom is unknown, but they form bulky masses occasionally about a foot square, which are carried by the tides into neighbouring areas. These masses are only a little heavier than the water, and hence are readily wafted about by currents.

In other groups of animals, for instance the cuttle-fishes, the same divisions occur in the eggs, some forming demersal masses of various shapes, or being fixed to foreign bodies, while others are pelagic. The majority of them, however, are demersal.

Summing up then the general facts concerning the early development of the food-fishes we find three leading types :—

A. That of the cartilaginous fishes with a minimum number of large eggs, with a maximum amount of 'protection' (in the widest sense) in the way of thick capsule, and great quantity of yolk, and a lengthened period of incubation so that the young is considerably developed before hatching.

B. That of the bony fishes with demersal eggs.

An abundance of small eggs, with a varying amount of protection, either by a tough capsule, concealment, colour and position or by direct contiguity of the parent, more or less close, and a fairly long period of incubation.

C. That of the bony fishes with pelagic eggs.

An immense number of very small eggs, with small quantity of yolk, an objective protection by translucent appearance but no parental protection whatever, a rapid period of incubation and more or less helpless larval form.

Stages after hatching. The later stages of development are usually classified for convenience into Larval, Post-larval and Adolescent. The larval stage extends from the period of hatching till the complete absorption of the yolk-sac, which in larval forms hangs like a large 'hernia' from the ventral surface of the newly hatched fish. During this period its movements are greatly hampered by this large sac of nutriment, which must be a very costly necessity to the young fish, as a source of attraction to many a hungry foe (see Herring).

The post-larval period extends from the end of the larval period till the time when the adult characters are assumed. This period is marked by numerous 'larval organs,' e.g. spines and pigmentations, which disappear before the adolescent stage, and must be regarded as secondary adaptations to the surroundings of its youth, affording, in the wide sense, means of defence or safety.

At the adolescent stage the young fish has arrived at an age when it is to all appearances an exact miniature of the adult, and further changes take place mainly in growth and maturation of the reproductive organs, though there may be important changes in the relative size of various organs and in pigmentation.

In the progress of the evolution of a fish from the moment of its individual existence to the adult stage we have carefully to distinguish the processes which take place side by side but which are quite different in their nature, namely development and growth. In the former we see the evolution of new organs and the progress of each to greater complexity, form and function rapidly differentiating till the adult stage of organism is reached. In the latter we have cell-division, resulting in increase of bulk, which continues long after the development, in the strict sense, has come to an end, namely at the end of the post-larval period, and which in fishes there is reason to believe only terminates with the death of the animal. In more highly organised animals, as birds and mammals, there is a fixed limit of growth when we may say that the organism has reached maturity and when the reproductive organs come into functional activity, and beyond which there is no further normal increase of bulk, but in the case of fish the size attained seems to depend largely upon the amount of nutriment consumed and upon the time over which the active consumption extends. Thus the size of a fish except in the widest limits is no criterion of the stage of its sexual maturity nor even of its age. It is to be noted that a curious parallel to this is found in the group of jointed animals; in these we find that the more lowly organised aquatic shelled crabs and lobsters grow throughout life and have continually and periodically to throw off their hard shells because they become too small for them, whereas the more highly organised land insects and spiders have no such troubles to contend with, but accomplish all their growth in an adolescent period before the sexual organs become mature.

CHAPTER II.

LIFE-HISTORY AND DEVELOPMENT OF A FISH FROM A PELAGIC EGG.

In the roe or ovary the egg of the fish is developed from a minute cell—quite invisible to the unaided eye—to a size that can readily be observed. During this process many important changes go on both with regard to the egg and its surroundings, and amongst others is the change from an opaque mass to a transparent glassy egg at maturity. This is due to the disappearance of the granules of the yolk which fills the egg, and of the contained bodies (nucleus and nucleolus), together with the formation of the female pronucleus. Moreover, at this time the egg increases considerably in size, especially in the pelagic forms, and hence the advantage of the provision whereby only a certain number assume this condition at a given period. If the whole of the eggs of such a fish, for instance as the cod, ripened simultaneously the body of the fish would be ruptured. The condition therefore is different from that in such fishes as the herring, wolf-fish, lump-sucker, sand-eel and salmon, in which the majority of the eggs ripen simultaneously and are shed about the same time.

The translucent eggs float about in the water, rising near the surface wherever the adults have shed them, and many are remarkably hardy. Thus the late Prof. Huxley having suggested in 1884 that perhaps the floating or sinking of the eggs was a question of temperature, a series of eggs of the flounder which had been fertilized on the 2nd May were placed in a test-tube on the 5th[1]. After standing an hour the majority were floating on the surface, one or two lay on the bottom, while others rested in mid-water. Placed in a vessel of water at 98° F. the eggs exhibited lively movements for several minutes, being carried up and down by the currents, but never remaining at the bottom. The test-tube felt quite warm, yet the eggs floated, and remained floating, as buoyantly in the warm water as in the cold, so that their floating in the sea is not a question of temperature. An interesting sequel, moreover, remains to be told in connection with this experiment. The test-tube had been placed aside and forgotten, but on May 10th while we were explaining the matter to Prof. Ewart of Edinburgh motion was noticed in the dusty test-tube, and it was found that the eggs which had been raised to a temperature of about 98° F. had given birth to little fishes, which thus survived the exigencies of their surroundings—both as regards temperature and water.

On the other hand severe frosts are fatal to eggs crowded in shallow vessels, in many cases actual rupture taking place, and the same occurs with large eggs, such as those of the wolf-fish, deposited on the bottom of the vessel. Thus to take the example of the eggs of the haddock during a severe frost in February. The earlier stages had been successfully passed, when the water at the surface of the vessels was frozen into soft flakes of ice—on which many of the eggs were elevated. No sooner was this ice broken than all the eggs were observed to present a whitish opacity and to sink to the bottom. Some of those which had floated in mid-water, or under the trickle from the supply-pipe, escaped destruction, but in a few days they also succumbed during a night of unusual severity, and after the embryos had been outlined. These circumstances, however, are for the most part artificial, for in the sea the danger from such extreme cold would be minimised, since the eggs in winter and spring are generally some distance from the surface[2].

Out of the little glassy sphere, after a longer or shorter interval (varying from a few days to a few weeks, according

[1] *Nature*, vol. 31, p. 555.

[2] *Ibid.*, vol. 34, p. 148. 1886.

to temperature), comes a minute and nearly transparent fish (Fig. 1), which at first is often as passive in the currents as the eggs themselves[1]. The tiny young in their helpless state are carried along with multitudes of eggs by every tide into sheltered creeks and bays, peopling waters in which, perhaps, no adults are, and finding both safety and food in the shallower water. These little larvæ, each furnished with a yolk-sac, are so fragile that they would seem to fall an easy prey to hosts of swimming companions, on which in the adult state they

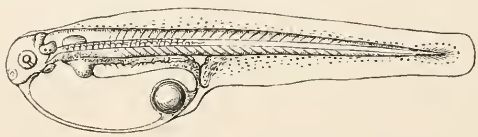


FIG. 1. Larval Ling, immediately after hatching.

would not even deign to feed. The larva soon, however, uses its tail for swimming and its breast-fins for balancing. Its shape is somewhat like that of a tadpole, partly from the large head, but mainly from the great size of the yolk-sac, which contains a store of nourishment on which the little mouthless creature, about 3 mm. long, sustains itself for a week or ten days. In this respect it somewhat resembles the young salmon, in which a much larger collection of the same food supports it about six weeks amongst the gravel in the spawning-bed of the river, though a closer scrutiny reveals certain essential differences. Thus the store of nourishment in the yolk-sac of the salmon is taken up by the blood-vessels which branch in a complex manner over the whole yolk; whereas in the young cod, though the heart is present and pulsating, not a blood-vessel at first is seen, and none ever enters the yolk-sac. The absorption of this nourishment therefore must take place by aid of the cells and tissues themselves,

[1] For some years the development of fishes has been studied by able workers, amongst others on the Continent, by Götte, Kupffer, Hoffman, Henneguy, E. Van Beneden, Osjannikov and Raffaele; in America, by Alex. Agassiz, Ryder, Whitman and Bashford Dean; while in our own country, Ransom, Klein, Cunningham, Prince, Brook and Holt have carried out similar researches.

and there is nothing specially wonderful in this, when the conditions in the endoderm of *Hydra*, and other instances of intracellular digestion are considered.

It has been mentioned that these minute and delicate little fishes are nearly transparent, and this is more or less the case throughout, though in the majority—even before they leave the egg—points of pigment appear here and there in the skin, so as to give them a distinctive character (Fig. 2). After hatching, these pigment-spots branch out in a stellate manner, thus becoming more evident, and it is found that in most cases each little food-fish has colours of its own. Thus the cod (Fig. 3) is known by its four somewhat regular black bands, the pigment on the haddock being less defined, and chiefly aggregated behind the head, the whiting by its canary-yellowish hue, the gurnard by its chrome-yellow, the ling by its gamboge-yellow, the flounder by its yellow and black, the turbot by its ruby-red, the sole by its stone-colour and so on. All these hues, however, become greatly modified during subsequent development, indeed the pigment in no group of vertebrates shows more remarkable changes between the young and adult states than certain of our food-fishes. Thus, for instance, the cod is characteristically

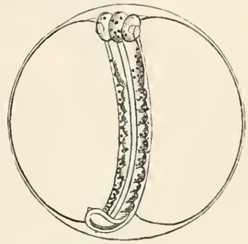


Fig. 2. Flounder, showing pigment in the egg.

Fig. 3. Larval Cod with black spots or bands, slightly enlarged.

Fig. 4. Aggregation of pigment in Post-larval Cod.

speckled in its tiny youth (Fig. 3), next it becomes more or less uniformly tinted, then the pigment groups itself somewhat irregularly on the sides (Fig. 4); thereafter it is boldly tessellated (Fig. 5), subsequently blotched with reddish brown, and finally in its adult condition it again puts on more or less uniform tints. The ling shows a similar series of transformations, the colours, however, differing in their arrangement, being marked with gamboge-yellow in its larval, slightly barred in its early post-larval stage, then the body becomes

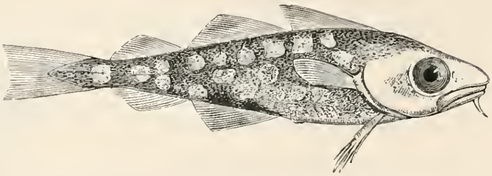


FIG. 5. Tessellated condition of young Cod (spirit-preparation).

more or less uniformly tinted in its post-larval phase, and the little fish is furnished with a pair of enormously developed and bright yellow ventral fins (Fig. 6)—so different from the short ones of the adult. It is next striped longitudinally when

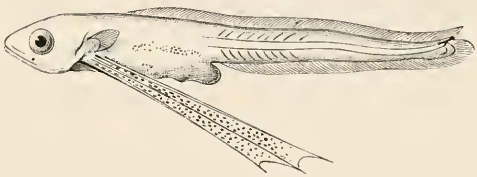


FIG. 6. Long-finned Post-larval Ling, enlarged.

about three inches long (Fig. 7), thus affording a great contrast to the tessellated condition of the young cod. In this stage an olive-brown band passes from the tip of the snout in a line with the middle of the eye, straight backward to the base of the caudal fin-rays. The pale ventral surface bounds it inferiorly, while a dorsal stripe with a beautiful opaline lustre

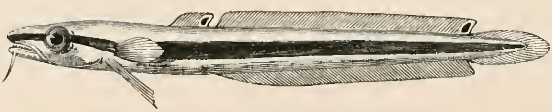


FIG. 7. Young Ling, about 3 inches long (in spirit).

runs from the tip of the snout, over the upper part of each eye to the tail, on which it is opaque white, thus giving the fish a characteristic appearance. The dorsal line from the brain backward is distinguished by a narrow edge of dull orange or pale olive, which relieves the colours formerly mentioned, and the general effect is varied by two black specks in the dorsals. When it is double the length (i.e. 6 or 7 inches) a complete change has taken place in its coloration (Fig. 8). Instead of being striped the fish is now boldly and irregularly blotched—both dorsally and laterally, the region of the white stripe being indicated by the pale and somewhat scalloped area dividing the dorsal from the lateral blotches. Fourteen or fifteen brownish blotches occur between the breast-fins and the base of the tail, and they are separated by the whitish areas, which thus assume a reticulated appearance, and both kinds of pigment invade the dorsal fins. Other touches of

FIG. 8. Young Ling in the barred stage. About half natural size.

dark pigment on the fins and tail increase the complexity of the coloration at this stage.

Again, some species, like the gurnard, have pigment over the yolk-sac before they are hatched, others have not. The dragonet in its post-larval (and pelagic) stage has its ventral surface deeply tinted with black pigment, while in the adult, a ground-loving fish, it is white, and the same occurs in the armed bullhead. The St Andrews cross in the eye of the post-larval stage in a kind of sea-scorpion is another remarkable feature (Fig. 9). No more interesting or more novel field indeed than this exists in the whole range of zoology; but the investigations need ships and boats, with expensive appliances, as well as persevering work for several seasons. We have only been able to open the field at St Andrews

FIG. 9. Head of young *Cottoid* with St Andrews cross in eyes.

by the help of the Trawling Commission under Lord Dalhousie, and subsequently by the aid of the Fishery Board. It may be asked, Why is all this remarkable variation in colour? Just for the same reason that the young tapirs and wild pigs are striped, or the young red deer spotted—the adults in each case being uniformly tinted. Such features indicate their genetic relation with ancestral forms having these marks; and, moreover, in the struggle for existence such variations in tint conduce to the safety of the young.

The view of Eimer that the markings in animals are primitively longitudinal would not suit for many fishes, notably for the young cod, ling, and Pleuronectids, and, indeed, Haacke has already pointed this out from a study of the Australian fish, *Helotes scotus*[1], the adult of which is marked by eight longitudinal bands, while young specimens present in addition a row of clear transverse bands which subsequently disappear.

The larval salmon enters the world of a size—though small—that is readily recognisable, viz., about three-fourths of an inch in length, but the marine forms under consideration, from their minute size and glassy translucency, are almost invisible to the naked eye—just a gleam of light broken by the passage of a different medium, or a tinge of pigment, arresting attention. Only in the wolf-fish or cat-fish (which is not much—though it ought to be more—of a food-fish) with its large egg, have we a size nearly reaching that of the salmon at birth.

We had left the larval fish tossed about by the currents and unable to struggle against them, now floating with its yolk-sac uppermost, or hanging in the water with its head downward, and again making spasmodic darts hither and thither. Soon, however, it gathers strength, and at the end of a week or ten days it glides actively through the water, and avoids both obstacles and enemies, the young cod nimbly escaping the forceps, poising

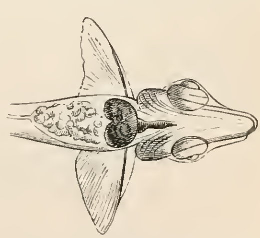


Fig. 10. Anterior (ventral) region of larval Cod with great breast-fins. Magnified.

[1] One of the Pristipomatidæ.

itself in the water with its large breast-fins (Fig. 10), and evincing both intelligence and dexterity. Nothing is more interesting than to observe the young fishes in the hatching boxes at Dunbar keeping their heads to the current as soon as strength permits. They form dense parallel rows like a vast regiment. Moreover, this activity greatly promotes respiration in those like the gurnard with a motionless mandible, the water being thus sent through the mouth and over the branchial region. Its mouth has now opened and the yolk-sac has been absorbed, while it feeds on the more minute of the little Copepods, especially those almost microscopic in size, that swarm in the surrounding water, and the consideration of which, before proceeding further, will form the theme of the next chapter.

CHAPTER III.

PELAGIC FAUNA.

The provision whereby such little fishes find in the ocean food suited to their capacities is one of the most striking features in nature, but it has only recently been carefully investigated[1]. It is a notion no longer tenable that during the winter and spring the sea, to a large extent, is devoid of the wealth of pelagic life—so characteristic of the summer months just as it is of the genial waters of the tropics. For many years, however, it has been known that a vast abundance of minute life of all kinds is present throughout the entire year—and from the surface to the bottom. Moreover, during the warmer months a constant succession of young forms rises from the eggs both of the sedentary and creeping animals on the bottom to the surface—where they sport in the summer sun, undergo certain changes, and again descend as they assume the form of the adult. The pelagic young food-fishes—swimming freely in the ocean—thus have a double chance at them—first in their very early stage as they rise, and again in their larger

[1] Vide "La faune pélagique du Golfe de Marseille," par Gourret, *Ann. du Musée d'hist. nat. de Marseille*, II., 1884. The pelagic fauna of our shores in relation to the nourishment of the young food-fishes, *Ann. Nat. Hist.*, Feb. 1887. Also Hensen and Möbius in *Fünfter Bericht der Kommission zur wiss. &c., der deutschen Meere*, Berlin, 1887, pp. 1 and 109. Recently various observations have been made on the Pelagic Fauna, perhaps the most important being those of Prof. Hensen in the *Plankton Expedition of* 1889, of Prof. Haeckel in his *Plankton-Studien*, of Mr Garstang on the Pelagic Fauna of Plymouth; and "The Sources of Marine Food," James J. Peck, *U.S. Fish Com.* 1895.

and later condition as they descend. The enormous numbers, countless variety, and ever-changing nature of the small animals, either directly or indirectly constituting the food of these little fishes, form an important feature in the economy of the sea. Now it is the arrow-like *Sagitta* that fills the tow-nets to bursting, now Appendicularians, again the Cydippe-group or Crustaceans (Thysanopods). Such animal forms comprise those long known in the British seas, besides others more familiar to arctic voyagers, or to the sunny waters of the Mediterranean, for with modern apparatus and persistent effort (thanks hitherto, at any rate, to the enlightened views of the Government acting through the Fishery Board) our knowledge is always extending.

It is a remarkable fact that it is primarily to plants in inshore waters that the abundance and variety of animals are in many respects due, especially if estuaries also debouch in the neighbourhood. Thus nowhere are the swarms of *Sagittæ*, Appendicularians, Crustaceans, and other forms of fish-food more conspicuous than in the midst of a sea teeming with diatoms, Rhizosoleniæ, and other algoid structures[1]. These nourish many of the lower forms upon which the crustaceans, annelids and other higher types feed, the latter again falling a prey to the fishes. Moreover, while the larger forms of the Copepods and other crustaceans, for example, afford suitable nourishment for the more advanced post-larval fishes, the multitudes of larval crustaceans (*Nauplii*) are adapted to the needs of the smallest larval food-fishes. Now this plant-life is specially rich in April and May, just when the larval and very young post-larval fishes appear more abundantly in the inshore waters, so that the cycle is nearly complete, viz. from the inorganic medium—through microscopic plant and larval crustacean—to the post-larval fish. We have mentioned the neighbourhood of an estuary as a prolific source of food for young fishes, and we need only explain further by instancing the case of mussel-beds, which for months pour countless myriads of larval mussels into the adjoining sea, far beyond the needs of the area as regards mussel-culture, and which form a favourite

[1] The fact that certain fishes feed on Infusoria has not been overlooked.

food of the little fishes at all stages, but especially from an inch and a half to three inches in length. These fishes feed on the young mussels as they settle down on the sea-weeds, rocks, and zoophytes in August, after a free-swimming larval existence. Like some of the forms indicated above, mussels live to a considerable extent on microscopic plants and various minute organisms contained in the mud of the estuaries and other sites, so that a rich and favourite food, universally liked by fishes, is the product of these uninviting flats. Moreover, in passing, it may be remarked that, while everywhere preyed on by the food-fishes, it occasionally happens that in turn the mussel proves a source of inconvenience to them, for, settling on the gill-arches of haddocks, the mussels flourish on a site so suitable for aeration and food that they by-and-by press out the gill-cover and impede respiration, just as the shore-crab (which is also fond of mussels) has its eye-stalks wrenched out by the slow but sure growth of the young mussels which have fixed themselves, wedge-like, in their sockets. Nemesis thus, by a chance of anchorage, converts a favourite food into a permanent inconvenience.

Again, in connection with the pelagic food of fishes, it is a well-known fact that adult cod are extremely fond of sea-anemones[1], and some of the rarest species may be procured in their stomachs, a feature by no means surprising when we remember that Abbé Dicquemare cooked and ate his sea-anemones with great relish, and wrote in their favour, as also did Mr Gosse in our country. Now, the pelagic young fishes, instead of roaming near the bottom in proximity to the anemones fixed on the rocks, and running the risk of being themselves captured for food, find in the inshore waters in summer the larval *Peachiæ*, worm-like anemones, in great numbers conveniently attached by the mouth to the little jelly-fishes (*Thaumantias hemisphærica*, and *T. melanops*) which occur in swarms in mid-water. Moreover, the somewhat larger young food-fishes (cod and green cod of 2—3 inches)

[1] A favourite bait for cod in some parts (e.g. Aberdeen and St Andrews), and from the fact, amongst others, that star-fishes do not molest them on the hooks, no bait is more successful.

show the same liking for the cœlenterate group, by browsing on the zoophytes (*Obelia geniculata*) which cover the stones and rocks with feathery tufts, yet the zoophytes are not much the worse for this treatment, for they by-and-by shoot afresh, and clothe the area once more with a minute forest. The rapidity with which such zoophytes grow is remarkable, though we must remember that in some cases, as in those (*Gonothyræa*) clothing the mussels in the Eden, the old stock naturally dies off after having produced swarms of pelagic young.

General Remarks on Pelagic Life. In the year 1888 one of us prepared a special report[1] on the pelagic animals of the Bay of St Andrews, a region which may be taken as more or less typical for the east coast of Scotland if not for a wider area. The investigations were carried out for a year and summarised for each month. From the results of previous observations made during the trawling expeditions, the pelagic forms may be classified into two great divisions, viz. the *Temporarily Pelagic* and the *Permanently Pelagic*.

In making these observations a different method from that of the Germans, especially Dr Hensen, was adopted. Prof. Hensen sank nets of a special construction, and calculated the amount of water passing through them in a given time, then having counted the various eggs and animals he apportioned them to the cubic foot of water. The method followed at St Andrews consisted of the use of tow-nets at the surface and the bottom, as well as in mid-water, the latter being a large net—24 feet in length—attached to a triangle of wood or bamboo—10 feet each way and hinged at two of the angles, the third being secured with spun yarn. The mid-water net has been of great service in regard to the post-larval and young fishes, indeed no other known form of net has been so successful in capturing these active forms[2]. If worked from a large steam-vessel this net, which is steadied at the required depth by a heavy bar of lead and floated by a galvanised iron float, requires much care in manipulation.

[1] *Seventh Ann. Rept. Fishery Board*, 1889.

[2] Dr Nansen amongst others carried one of these St Andrews nets with him in his expedition to the North Polar regions.

Another net has been extremely successful at St Andrews in examining the pelagic fauna near the bottom, viz., one constructed after the manner of a small trawl. The trawl-heads are of very light iron, the beam a slender bar of elm, 8 feet 6 inches long, and the net (18 feet long) is in the form of a trawl-net, but composed of cheese-cloth, with a terminal region 3 feet in length of fine cotton cloth. The mouth of the net is elevated about 9 inches from the ground by being drawn "taut" between the trawl-heads, and has an oblique aperture of 3 feet from beam to foot-rope. This is a fatal net for larval fishes and the multitudes of invertebrates at various stages that haunt the bottom-water in early spring, and should be used only for a short time.

The mathematical apportionment of the animals composing the pelagic fauna therefore falls short of the German method (Prof. Hensen's), but for all practical purposes connected with the fisheries the plan here adopted is fairly satisfactory. It gives at a glance the vast resources to be found in the sea for the nourishment of the food-fishes—resources ranging over the vegetable as well as the animal kingdom, the latter comprehending representatives of every class from the fishes downward. Moreover, an intimate acquaintance with this pelagic fauna alone, and leaving out of view for the moment all reference to the multitudes of animals in sand and mud, under stones and elsewhere, and which are all beyond interference by man, demonstrates the unsatisfactory position of those who labour, either through misapprehension or simply *ad captandum*—to prove that a beam-trawl deprives the food-fishes of nourishment by rendering the sea-bottom barren (*sic*)—just as a roving enemy might starve the flocks of a population by burning the grass.

The importance of the pelagic fauna in supplying nourishment for fishes cannot be over estimated, for while the adults of many food-fishes might obtain support from the bottom-fauna alone, it is certain their post-larval and young stages could not. Further, the remarkable adaptation whereby the most minute post-larval forms, such as the very young cod, find in the pelagic organisms every want supplied is a striking feature. Again, the terminal portion of the intestine in the larval herrings captured in March shows a deep greenish coloration, which may be connected with chlorophyll, the green colouring matter of plants. Moreover, even so minute a pelagic form as an Infusorian is occasionally, as for instance by the sardines, swallowed in masses as food.

There is no more interesting part of the inquiry than the gradual advent in the early part of the year of the larval fishes, and their great abundance in the spring months, such as March, April and May. Then, while the larval stages of a few still appear in the warmer months, viz. June, July, and August, the predominance of post-larval and young stages are the main features. These become rarer in the pelagic fauna as winter approaches, and finally almost cease to occur in the nets—probably in many cases as much from their increased power and activity as from their scarcity.

In the same way the larval stages of mussels and other shell-fishes of importance make their appearance at a stated period, continue in great profusion for some time, and then gradually diminish and disappear. In the case of the mussel the advent of the larval forms in swarms is in touch with the previously ripe condition of the adults on the beds, the long-continued presence of certain of these larvæ being connected with the later maturation of the reproductive organs in the littoral and often stunted examples so abundant in many parts, especially on the margins of rocks.

Besides the special interest of the pelagic fauna in connection with the fisheries, the bearing of many of the facts, e.g. the appearance and disappearance of multitudes of swimming jelly-fishes, is of a novel kind, since even the most recent and most authoritative investigators of the subject, such as Prof. Haeckel, do not exhaust the question. Little indeed has been done in this respect since the days of Edward Forbes, with the exception of the Notes made at the Naples Zoological station, and those at the Plymouth Laboratory.

The pelagic fauna round the British shores seems to have many features in common, but the presence of the phosphorescent *Noctiluca* in the south, of the large *Arachnactis* in the north, of the purple *Ianthina*, of *Velella* and of Salps on the west, and of Cydippe, *Lesueuria* and Appendicularians, on the east, indicates certain regional distinctions.

Though not strictly belonging to any special group or to any special season, the pelagic mud carried by the bottom-water plays an important part in feeding the sedentary mollusks, ascidians, cirripedes and other fixed types. It is only necessary to examine the stomachs of ascidians and of edible mollusks, such as the oyster and the mussel, to observe the large number of Infusorians, Diatoms and other Algæ, the abundance of sponge-spicules and organic matter of various kinds, which have thus been swept by currents in their neighbourhood amidst a plentiful supply of mud and sand.

Pelagic Life during the various Months. January. It is unnecessary in the present work to go fully into the nature of the pelagic fauna during each month: the salient features alone will be alluded to. Thus in January the floating eggs of food-fishes were for the most part absent, as were also the larvæ, though young sprats were occasionally found near shore. Prominent amongst the mollusks was *Spirialis.* Crustaceans were in great force, such as Thysanopods, sessile-eyed forms (e.g. *Parathemisto,* which attained its maximum this month), with swarms of Copepods. The arrow-like worms (*Sagittæ*) were often in great profusion, indeed it was in January that the tide stranded them on the west sands many years ago, when first found in Scotland by the lady to whom the "*St Andrews Fauna*" is dedicated. They were observed to sparkle along the line of the retiring tide in the setting sun like needles of glass. The equally translucent *Tomopteris,* an annelid of great beauty, was also very common. Numerous jelly-fishes likewise thronged the sea, such as *Tima, Stomobrachium* and *Aglantha*, with the Ctenophores—Cydippe, *Lesueuria,* and Beröe. The mitre-like *Aglantha* was one of the most characteristic jelly-fishes of the winter months from January to April, and was frequently in great numbers. Of Infusorians, *Ceratium tripos,* a phosphorescent form, was in abundance, and Radiolarians occurred occasionally. Amongst plants, diatoms and the lower algoids were frequent—with a few Rhizosoleniæ. The sea is thus very different from the land, since even in mid-winter a profusion of animals—both minute and delicate, together with many microscopic plants—are carried about by its currents or swim actively in its midst.

February. During February the pelagic eggs of the food-fishes were more noticeable, and included those of the plaice, long-rough dab, dab, haddock, and green cod—along with various larval and post-larval stages—amongst others those of the large form resembling a goby (*Crystallogobius*) and young wolf-fishes. Numerous young Appendicularians represented the allies of the vertebrates. Of shell-fishes, minute bivalves, numerous young examples of the pteropod *Spirialis* and a few of another example of the same group, viz. *Clione*, were the most noteworthy. No form is more beautiful than the latter (*Clione*), which was first observed by Prof. Prince, the gaily coloured little sea-butterfly, as it has been aptly termed, dancing to and fro in the water with its extended arms, like a deft human swimmer. The larval form (*Cyphonautes*) of an encrusting species allied to the sea-mats was the only example of the Polyzoa. Crustaceans were in great numbers, such as forms mentioned under last month, and especially *Parathemisto*, besides many additions. Of Annelids the females of a species (*Autolytus*) carrying eggs on the under surface of the body, and the male with bifid palpi, were not infrequent, while the sexual forms of another (*Nereis*), which undergoes strange modifications of structure and habit at the reproductive season, occasionally occurred. Various larval forms of the Nerine group also abounded. *Sagittæ* were in swarms throughout the water. The jelly-fishes in addition to *Tima* and the prevalent *Aglantha*, included an occasional *Thaumantias*, besides the Ctenophores formerly mentioned, some, such as Cydippe, in the young condition. Towards the end of the month also the saucer-like divisions of the hydroid stage in the development of the abundant yet pretty jelly-fish *Aurelia* became frequent. They often indeed appeared in swarms in the tanks, having been pumped up from the sea. Of the elementary types various species of Infusoria and Radiolarians were captured. Plant-life was present in the shape of multitudes of spores, minute algæ, a peculiar algoid body like a minute radiolarian, and numerous diatoms. In southern waters, e.g. the estuary of the Thames, the brilliantly phosphorescent *Noctiluca* was conspicuous, and occasionally at Plymouth the Siphonophore *Diphyes*.

March. A great increase took place in the number of pelagic eggs of fishes in March, those of the haddock, ling, rockling, gurnard, plaice, dab, long-rough dab and flounder having been met with; while towards the end of the month larval cod, plaice, rockling, and the demersal eggs of the gunnel and other forms occurred. The most conspicuous larval fish, however, was the herring, which was found in vast swarms in the bottom-nets in such bays as that of St Andrews, where the adults are seldom seen in numbers. Young appendicularians were also frequent and in considerable profusion, yet at Plymouth ripe adults were common. The pelagic shell-fishes consisted of a few examples of *Spirialis*, other larval univalves, a few minute bivalves, including mussels. The cuttle-fishes were represented by a young squid an inch long. The larvæ (*Cyphonautes*) of an encrusting Polyzoan were plentiful.

The crustaceans again comprised many adult opossum-shrimps, the larvæ (*Zoeæ*) of the shore-crab, the larvæ of shrimps, and myriads of larvæ of sea-acorns. The Copepods were in swarms, *Tomopteris* and the larval annelids were very abundant, while *Sagittæ*, which form a favourite food-supply of fishes, were in myriads.

No larval star-fishes were present, but minute brittle-stars occurred the first week. Larval sea-anemones, the young of true jelly-fishes, swarms of developing small jelly-fishes (*Hydromedusæ*) of various species were frequent. The ctenophores (*Lesueuria* and *Pleurobrachia*) were common, and larvæ of the former were also captured.

April. No month presented a more conspicuous collection of pelagic eggs than April, the surface of the sea in many parts abounding with vast multitudes of them. They consisted chiefly of eggs of cod, haddock, whiting, poor cod, rockling, gurnard and sprat amongst round fishes, and of plaice, dab, long-rough dab, brill and flounder amongst flat fishes. The larval and post-larval forms comprised herrings, sprats, gadoids of various kinds, gurnards, swarms of sand-eels, besides suckers, long-spined *Cotti* and others. The appearance of multitudes of sand-eels in the bottom-nets, as well as by and by at the surface, was a characteristic feature.

While the Appendicularians occasionally showed themselves in February, yet their enormous numbers during April and at the beginning of May far surpassed the earlier period. The huge mid-water net was filled like a balloon with them and their gelatinous "houses," so that the patience of the boatman was well-nigh exhausted by the constant and heavy strain, as well as the frequent ruptures of the net. It was a relief when they disappeared. There could be little doubt that like other ascidians they were eaten by fishes, and from their prodigious numbers they were thus important. They have long been known to occur in Scottish waters, for Edward Forbes in 1845 found that the cloudy patches of red colouring matter in the sea off the north of Scotland consisted almost entirely of them. They were also frequently met with all along the eastern shores during the work for the Trawling Commission, but their prodigious numbers were only clearly made out at St Andrews. Their food apparently consisted of the peculiar gelatinous algoid masses and similar structures, and many were ripe.

Of pelagic shell-fishes the most remarkable was the graceful pteropod, *Clione*, hitherto considered one of the rarest British marine animals, indeed the late Dr Gwyn Jeffreys, long the authority on the group, could only quote Dr Leach, who found in 1811 several mutilated specimens on the rocks of the west coast, and a single living one off the coast of Mull. It forms a prominent part of the food of the right whale in the Arctic Sea, and is a prize for any food-fish, though the size fell considerably short of the northern examples.

Crustaceans were represented by vast multitudes of Schizopods, which were occasionally stranded like lines of chaff along the beach, or made the littoral pools semi-solid. They were eagerly eaten by most food—and other fishes. Larval cirripedes in various stages and allied forms—with myriads of Copepods and other minute crustaceans besides larval stages (*Zoeæ*) of the higher forms, still further augmented the list.

An increase in the numbers of the larval annelids also took place in April. The sexual forms of Nereids and the tinted Syllids (*Autolytus*) bearing eggs were also common, along with the translucent *Tomopteris* and *Sagitta*, though the latter were sometimes less conspicuous than during the previous month.

The jelly-fishes, especially the smaller forms (*Hydromedusæ*), were plentiful, some bearing buds from the central stem (*manubrium*) or at the margin, as in *Lizzia* and *Hybocodon*, others issuing in swarms from the hydroid stocks, as in *Clytia*. The pelagic stages (*Arachnactis*-stage) of *Peachia* were also present. The ctenophores were abundant, and young stages were occasionally met with.

Minute forms of plant-life crowded the water, and their great profusion had a close relation to the abundance of various pelagic animals.

May. Amongst the pelagic eggs of the food-fishes that of the gurnard was prominent. It was accompanied by those of the whiting, pollack, poor cod, rockling, green cod, sprat, haddock, plaice, dab, lemon-dab, brill, topknot and others. As a rule, however, during easterly gales most of the eggs were found in the lower parts of the water. Post-larval gadoids were abundant, and during the month it was easy to follow some of these to unmistakeable young cod. There were also numerous clupeoids, myriads of sand-eels and young flat fishes, besides the larval and post-larval stages of many inshore fishes, such as the lump-sucker and armed bullhead. On the south coast pelagic brill were common in the inshore waters.

The Appendicularians occurred generally throughout the month in all the nets (surface, mid-water and bottom). The largest were frequently found in mid-water, and they were quite as fine as any procured during the Challenger expedition. It sometimes happened that when certain algoids (Rhizosoleniæ) occupied the upper regions of the water the Appendicularians held the lower regions.

Young mollusks were represented by minute univalves like *Velutina* and many others like *Natica*.

Crustaceans from Copepods upwards were plentiful, and larvæ (*Nauplii* and *Zoeæ*) were especially prominent, some of the latter being in the large-eyed stage towards the end of the month, while the larval sea-acorns (Cirripedes) had also fixed themselves as Cypris-larvæ at the same period.

The pelagic larval annelids had increased in number and variety, and the larger adults, such as the sexual forms of Nereids, *Tomopteris* and the Chætognath, *Sagitta*, were likewise frequent.

Amongst Echinoderms the reddish eggs of sea-cucumbers were often captured. These issue as long strings but afterwards break up into isolated eggs. As a rule the 'painter's-easel' larvæ were later in making their appearance, but occasionally some were procured as early as the 14th May in the northern waters.

The various forms of jelly-fishes were largely augmented, especially the Hydromedusæ—amongst which the somewhat rare *Hybocodon* was numbered. It was interesting to watch the growth of the true jelly-fishes as the month advanced. The Ctenophores were abundant, viz. small examples of Cydippe from $\frac{1}{8}$ to $\frac{1}{2}$ an inch in diameter, and the brilliantly phosphorescent *Beroe* and *Lesueuria*, the latter often in swarms; yet hitherto it had been unknown in Britain, though discovered in the Mediterranean in 1841 by the distinguished French zoologist, Milne-Edwards.

Minute algæ were plentiful, such as the curious gelatinous masses alluded to in April, Rhizosoleniæ, diatoms and myriads of spores. Rhizosoleniæ were sometimes so abundant as to interfere with the working of the nets, the pores of which were plugged—thus retaining the water and masses of Appendicularians with their gelatinous "houses," so that the boat was anchored or the ropes of the sails broken.

June. In June the pelagic eggs became less conspicuous than the post-larval and young stages of fishes; yet eggs of the gurnard, rockling, sprat, dragonet, sole, solenette, dab and flounder were still present. The young gadoids for instance were prominent pelagic forms during the month—ranging from 7 mm. with an entire marginal fin, to 24 mm. They fed on larval cirripedes and other forms (*Nauplii* and Copepods). Some of the smaller of these were shorter and stouter—with a shorter snout and heavier head, while the jaws were less lanky and the permanent rays of the fins seemed to be far advanced for their length. They appeared to be mere varieties of the cod, and it has since been found that the young haddocks seek the offshore water along with many of the whiting, while the young cod pass inshore to the laminarian region. Young cod, again, of an inch and a sixteenth in length and having tessellated pigment on the sides, appeared in the bottom-nets towards the middle of the month, and older forms were captured in the trawl along with young clupeoids an inch and seven-eighths. Young sand-eels were still abundant, along with young gobies from 3 to 8 mm., and other forms already mentioned.

Appendicularians were somewhat less common than in May, only a few small examples now and then appearing. Rarely were they numerous. At Plymouth salps sometimes abounded.

Pelagic young mussels now appeared in considerable numbers in the tow-nets, their size varying from ·0055 to ·014 inch. It is during this month that they fix themselves on the various ropes and other parts of the salmon-stake-nets.

The pteropod, *Spirialis*, with other minute univalves were abundant. The larval form (*Cyphonautes*) of an encrusting Polyzoan was common.

Crustaceans everywhere abounded. In the bottom-nets Copepods were especially prominent, and stragglers from their dense ranks often sought the upper regions of the water. They were accompanied by swarms of the viviparous *Evadne*. The later stages (Cypris-stage) of Cirripedes of many larvæ of the shore- and porcelain-crabs were frequent, while the young of other crustaceans also occurred.

Numerous examples of pelagic young annelids of many species were procured, all of which form a favourite food of the young fishes. *Tomopteris*, in the adult state, with the fully developed reproductive organs, was not uncommon. The rare *Mitraria* was also occasionally found. *Sagittæ* were few and small.

The 'painter's-easel' larvæ (*Plutei*) of brittle and other star-fishes and of the sea-urchin were procured in considerable numbers towards the end of the month—sometimes sooner.

On one of the small jelly-fishes, the larval stage of an anemone (*Peachia*), frequenting the sand, was often found attached to the disc by the widely open mouth and tentacles. The young anemones are thus carried about—without effort on their part—by the beautifully transparent and festooned coach. But while this is so, they are also placed within the reach of the active young gadoids and flat-fishes—both of which probably diminish their numbers at this stage as well as subsequently when they are settling in the sand. No food is more tempting.

The number and variety of these little jelly-fishes were remarkable, indeed on many occasions they thronged the water. Moreover, the enormous quantity of eggs given off by them must largely increase the food of other invertebrates and even of the larval and early post-larval fishes. A consideration of their life-history, further, is a curious comment on the views of those who imagine that the bottom of the sea can to a serious extent be rendered barren by the use of the trawl. While the Hydromedusæ were thus generally plentiful, the true jelly-fishes (e.g. *Aurelia* and *Cyanea*), on the other hand, were variable in their appearance, sometimes abounding in June, while in cold seasons they were few.

Infusoria (*Tintinnus*, *Ceratium* and *Peridinium*) were especially numerous in the bottom-water, and though not previously mentioned, occurred every month of the year. The phosphorescence of *Ceratium* caused the interior of the fine tow-net when suddenly jerked at night to gleam like a fiery funnel.

Amongst algoid forms Rhizosoleniæ were common at the beginning of the month, but gradually diminished. Diatoms, the gelatinous algoid masses, and spores frequently occurred.

July. The pelagic eggs of July were not numerous, though the variety was considerable, viz. gurnard, sprat, rockling, dragonet, weever, and the eggs of the frog-fish in long gelatinous ribands, besides eggs of the dab, topknot, lemon-dab, turbot, sole and little sole. Amongst the young fishes were gadoids, clupeoids (15—17 mm.), sand-eels (7—12 mm.), rocklings, gunnels, gobies, lumpsuckers, dragonets, pipe-fishes, brill (20 mm.), topknots and the flat fishes. Moreover, abundant food for the adult fishes was present in the shape of larger forms, such as sprats of 2¼ inches, gurnards 3 to 4 inches, and whitings of a smaller size.

Throughout the month, Appendicularians were seldom absent from the mid-water and bottom-nets, but if the weather was cool they did not appear on the surface till the latter half. As a rule—whether numerous or few—they were small.

Young mussels and other bivalves, with the little pteropod, *Spirialis*, had now reached the surface, but they were most plentiful near the bottom.

The larval forms of Polyzoa were abundant, e.g. *Cyphonautes*, which agreed with the able description of Prof. Allman, who found it in the Moray Frith. Schneider, again, traced it to the adult condition (*Membranipora*). The wonderful larval form of *Phoronis*, viz. *Actinotrocha*, was common this month.

As in June, crustacean life swarmed from the surface to the bottom, though now and again the one or the other species would be more abundantly captured. On certain grounds some species (e.g. *Boreophausia*) rendered the nets semi-solid, and attracted many fishes. Moreover the pinkish oil of these crustaceans would certainly suffice to colour the muscles of the fishes which devoured them—if coloured they could be by such food[1].

A great number of pelagic annelids in their larval stages were present, most of the littoral forms being represented. After this nomad existence they settle down in chinks of rocks and under stones, in sand or in mud, or as borers in stone. The wealth of life, in this group alone, was great. Besides the annelids, *Sagittæ* occasionally appeared in masses.

'Painter's easel' larvæ of Echinoderms (sand-stars etc.) thronged the water, along with larval forms of the common cross-fishes, of the holothurians and *Synaptæ* (Bipinnarians, Brachiolarians and Auricularians).

The various kinds of jelly-fishes were in great profusion and

[1] See Marion's *Pelagic Fauna*.

many of them ripe. So plentiful were many of the smaller Hydromedusæ that occasionally they were beached on the sands. Cyanea and other types reached the surface.

The Infusorians were especially numerous at the surface on fine days, and during the still warm evenings, forming a thick phosphorescent coating (*Ceratium*) to the tow-nets, and sparkling with every stroke of the oars. It is well known that even these (e.g. *Peridinium*) are found in masses in the intestine of the sardine.

The algoid contents of the nets sensibly increased in July, probably from the profusion of spores and rapid general growth, and they were abundant offshore as well as inshore.

Altogether the enormous variety in pelagic life—both plant and animal—constituted a conspicuous feature in July.

August. During August the number of floating eggs had considerably diminished, those of the gurnard, rockling and sprat being most conspicuous—along with a few of the sole, turbot, and lemon-dab. The midwater-net inshore also showed a diminution of the post-larval round fishes, though taking the offshore and inshore together, a considerable number of small forms were still present. Two sizes of clupeoids, viz. 5·5 to 8 mm. and 16 to 18 mm. were yet obtained. There were also families of gurnards ranging from 5 to 10 mm., sand-eels at 9 mm., rocklings in great variety at the surface from 4 mm. to silvery mackerel-midges of an inch or more in length; besides young whitings at $1\frac{1}{4}$ in., Montagu's suckers, gunnels, skulpins, lumpsuckers from 6 mm., gobies, pipe-fishes and pleuronectids (flounders, etc.) from 7 to 11·5 mm. Perhaps the most frequent round fishes in the nets were gobies.

Small appendicularians were not unfrequent during the whole month; while the larval form of *Phoronis* (*Actinotrocha*) was a special feature, the transformation of the one into the other being followed with ease.

Swarms of young mussels and other bivalves were present in both surface- and bottom-nets; while *Spirialis, Natica* and others in the veliger-stage represented the univalves. Occasionally a young cuttlefish was likewise captured. Molluscan life indeed was plentiful.

Polyzoa were still represented by various larval forms.

No diminution in the wealth of crustacean life took place in August, but it rather seemed more plentiful. While many of the higher kinds were still in their larval forms, such as porcelain crabs, others were in the large-eyed stage or beyond it. A marked feature off the Forth was the abundance of the post-larval stages of the Norway Lobster, which, mingled with the long trailing tentacles of jelly-fishes (*Cyanea*), formed an inextricable rope or chain. The larval stages (*Nauplii*) of the lower crustaceans likewise were still common. Thus the waters abounded in this rich food, the swarms of the post-larval stages being especially suitable for the growing fishes.

From the beginning to the end of the month the various remarkable larvæ of Echinoderms (starfishes, sea- and heart-urchins) in various stages thronged the water—both surface and bottom; moreover, many minute sea-urchins, heart-urchins, sand-stars and brittle-stars showed that considerable advancement had been made in growth. The long spines of some of these larvæ may be protective, but—notwithstanding—it is probable that they are largely diminished by the young food-fishes.

The jelly-fishes were in considerable profusion during the month, and their distribution seemed to be more general throughout the water. Occasionally it happened that a square mile of sea was densely covered with the common jelly-fish with the lilac bands (*Aurelia*). The uncertainties in connection with pelagic life were seen in the case of *Beroë*, which was plentiful the first week and afterwards disappeared.

The Infusorians were abundant, especially at the bottom, and those at the surface were occasionally accompanied by Radiolarians.

The minute algæ, such as Diatoms, spores, Rhizosoleniæ and others, were as plentiful as in July, and now and then were stranded as a greenish scum on the sands.

September. The study of the pelagic eggs of fishes in September presented a contrast to that in the preceding months, for they had disappeared. A great diminution likewise had taken place in the post-larval food-fishes. Young gurnards, however, were not uncommon, varying in size from 5 to 12·5 mm.—thus showing an increase on the previous month. Moreover young clupeoids—from 7 to 16 mm.—of the autumn brood had made their appearance, the larger forms only after the middle of the month. A single gadoid of 5·5 mm., rocklings from 6 to 24 mm., larval sand-eels and pleuronectids from 5 to 11 mm. completed the list of the food-fishes. Gobies were still frequent, the extremes in length being 6 and 21 mm., while the majority were about 7 mm. Skulpins from 3·5 to 10 mm. were often met with, the former appearing at the beginning of the month, and having the tapering larval tail with permanent rays below. Young sea-scorpions (*Cotti*) of 9 mm., bimaculated suckers of 7·5 mm., young whiting from 1 to 3 inches, young gadoids of similar size, and young pipe-fishes were likewise obtained.

Appendicularians were fairly numerous throughout the month, as also was *Actinotrocha*, with young *Phoronis*.

Young mussels were still plentiful, though not in profusion, and they were accompanied by other bivalves and many univalves. The larval Polyzoan, *Cyphonautes*, was still common.

The crustaceans were apparently as numerous and varied as in August. Larval stages also (*Nauplii* and *Zoeæ*) were prevalent. They formed an almost inexhaustible store of nourishment for the smaller fishes.

The bottom-nets especially abounded in the larval and post-larval annelids, their profusion in all the nets being remarkable. Young examples of most of the littoral annelids also made their appearance. *Sagittæ* from 12 to 16 mm. were frequent.

The larval Echinoderms were less numerous than in August, but yet they occurred in almost every haul of the surface- and bottom-nets—together with a considerable number of minute star-fishes.

In the mid-water-nets jelly-fishes (Hydromedusæ) were frequent at the beginning of the month, but were rare in the surface-net. The ranks diminished as the month advanced, probably by the death of the jelly-fishes after the discharge of the eggs.

Infusorians in considerable numbers occurred in almost every net, especially in mid-water.

Diatoms and other algoids were as abundant as in August.

October. No pelagic eggs of fishes were found in October, and the pelagic post-larval and very young fishes were few in number. They consisted of clupeoids of the autumn series, from 17 to 18 mm., with permanent rays appearing in the dorsal fin and in the tail; rocklings; an occasional gurnard of 16 mm., various gobies and a stray pipe-fish or two.

Young appendicularians were met with several times.

The pelagic shell-fishes were still procured in considerable numbers, the majority of the bivalves being apparently young mussels, though other forms were likewise present. Larval univalves were frequent.

Cyphonautes (the larval stage of an encrusting Polyzoan) continued throughout the month.

The bottom-nets teemed with minute crustaceans from the beginning to the end of the month. Larval types (Nauplii and the Cypris-stage) were plentiful. The paucity of the larval phases of the higher crustaceans was a marked feature, but very young forms were often met with.

The larval annelids showed little diminution in their numbers in the bottom-net, and their variety was great—showing how ample the food-supply of the smaller fishes is from this source. Arrow-worms occurred sparingly at first, but were numerous at the end of the month.

The diminution of the larval Echinoderms was most marked. Only a few 'painter's easel' larvæ (Plutei) appeared at the surface about the middle of the month.

The small jelly-fishes (Hydromedusæ) were still occasionally numerous, though the species were limited. They were, however, comparatively rare in the surface-nets. The ctenophores were represented by myriads of *Cydippe,* while *Beroë* was generally present in most hauls of the nets.

Infusorians occurred in considerable numbers, and one form (*Ceratium tripos*) was sometimes in vast profusion.

The pelagic diatoms and algæ were in great variety, and quite as numerous in the bottom- and surface-nets as formerly.

November. The post-larval fishes had almost but not quite disappeared in November. Clupeoids of 14·5 to 16·5, bimaculated suckers, an occasional pleuronectid with the eye on the ridge (11·5 mm.), and gobies from 18 to 23 mm. were obtained. The contrast to the preceding months was thus marked.

The shell-fishes were represented by a few bivalves—apparently mussels, and a few minute univalves—both groups occurring only in the bottom tow-nets. *Cyphonautes* was the only larval polyzoan.

Minute crustaceans (*Copepods*) were numerous, with occasional swarms of the large-eyed stages (*Megalops*) of crabs.

Amongst annelids the larval forms of certain kinds (*Nerine*) and small examples of others (*Tomopteris*) occurred. Arrow-worms on the other hand often were in profusion and of large size. They took the place of the crowds of small jelly-fishes of the earlier months.

The appearance of a mitre-shaped jelly-fish (*Aglantha*) indicated the presence of the fauna of winter, the others being *Tima* and the ctenophores—*Cydippe, Lesueuria* and *Beroë* in considerable numbers. The majority were beneath the surface.

The Infusorians and algæ were as numerous as in the previous months, and the former occasionally appeared in the surface-net.

December. In December the post-larval fishes appeared to be extremely rare, though the older stages of various forms were met with.

Larval univalves in limited numbers represented the shell-fishes. The larval Polyzoan, *Cyphonautes*, was still common.

Crustaceans were often in multitudes, the sessile-eyed forms also being present (e.g. *Parathemisto*), and a few larval forms (*Nauplii*) were still found. There was no lack of nourishment for fishes in this group.

The larval annelids were inconspicuous, but a few adults still occurred. Arrow-worms, on the other hand, were remarkably prevalent, and of large size. They formed a considerable element of the food of fishes at this season.

Contrary to what might have been anticipated one or two 'painter's easel' larvæ (*Plutei*) of Echinoderms still appeared.

The same jelly-fishes mentioned in November were present, with the addition of one or two others. The numbers of the Ctenophores were frequently large.

Infusorians of the same species as formerly were often in considerable profusion; while plant-life—such as Diatoms, spores of algæ and minute algæ—was plentiful throughout the month.

In connection with a general collection of pelagic larval and post-larval fishes—chiefly the latter—it is interesting to note that if they are arranged according to the months a spindle is formed, with the thick central mass in May, April being next, and followed by a nearly equal series in June, July and August, while the tapering at each end, viz. the beginning and end of the year, is marked. When the same collection is grouped according to species, the first place is held by the pleuronectids, then follow in order the gobies, gadoids, sand-eels and cottoids, after which come Montagu's suckers, the clupeoids, dragonets, armed bull-heads, rocklings and gunnels. No particular weight need be put on this remark, but it gives an idea of the comparative abundance of young fishes usually captured in the tow-nets.

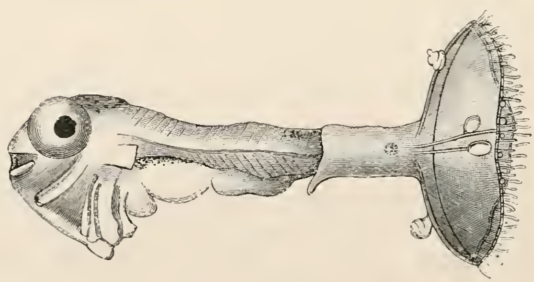


Fig. 11. Jelly-fish, with disc everted, partly engulphing a post-larval flounder. A. T. M.

CHAPTER IV.

LIFE-HISTORY AND DEVELOPMENT OF A FISH FROM A PELAGIC EGG.

THE perusal of the foregoing chapter on the pelagic animals will demonstrate the inexhaustible nature of the food provided for fishes at every season of the year, and, further, will indicate how little reliance is to be placed on the opinions of those who imagine that man can to any serious extent, by any method of fishing at present practised, denude the bottom of the ocean of its inhabitants. It has already been shown by one of us, that even though it were granted that a particular area of the sea were by the agency of man rendered "barren" the next tide would bring in a sufficient stock of temporarily pelagic forms to settle on the bottom and re-people the hypothetical waste, and that with rapidity.

Under this rich food, the young fishes grow apace—head and eyes, mouth and accessory organs, body and fins—all rapidly increase, and the little fish, hatched in the spring, say from March to May, is soon in what is known as the post-larval stage, that is, has a mouth, has lost its yolk-sac, has assumed a more or less uniform tint, and has gill-fringes and teeth. It is about a quarter of an inch long, and is both active and intelligent, the large head and large eyes of the young food-fishes being at this stage specially conspicuous, and in marked contrast with such as the sea-scorpion (*Cottus*). The marginal fin is continuous at a quarter of an inch, and the lancet-like termination of the caudal end of the body is noteworthy.

About this time the ventral fins of the pelagic fishes first make their appearance, for hitherto they have managed to do without them. Moreover, these fins in some, such as the rockling and ling, undergo remarkable development, forming in the latter (Fig. 6) a pair of great ventral wings conspicuously coloured yellow; yet in the adult (a ground-fish) they attain no greater dimensions than in the cod, both having at a certain stage soft, free filaments or tactile processes at the tip. The ventral fins in the post-larval rockling are equally large, the distal half being black, so that at first sight the little fish when captured seems to possess a great ventral spine on each side

Fig. 12. Post-larval Rockling, enlarged.

(Fig. 12). In the post-larval gurnard again, the huge breast-fins form a drapery for the entire body when folded back, only the tip of the tail extending beyond them (Fig. 13). They are indeed proportionally as large as in the southern flying gurnards, but in these the fins reach full development only in adult life, while in the young stages they are comparatively small—exactly the reverse happening in the grey gurnard of

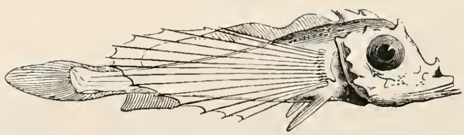


Fig. 13. Post-larval Gurnard, enlarged.

our seas. The presence of the broad arches of pigment on the breast-fins of several forms, such as the present species, the green cod, and the armed bullhead, is also an interesting feature. We have not yet read the riddle of all these changes, but in the ling the great ventral fins are probably connected with its roaming or pelagic life, and this explanation would also suit in the cases of the rockling and the armed bullhead, both, in their mature state, seeking their food on the ground.

The little fishes at this stage are still more or less translucent, except in the region of the eyes, which are silvery, and on the parts where the pigment occurs. Moreover, their fondness for a minute reddish Copepod (*Calanus finmarchicus*), which occurs in myriads around them, gives the region of the stomach a faint pinkish hue from the translucency of the tissues. Soon, however, pigment appears—at first chiefly along the dorsal and ventral margins of the body—and, by-and-by, foreshadowing in the cod those peculiar squares which give the sides, at a somewhat later stage, their tessellated or tartan-like aspect. Besides, they are found nearer the bottom of the water, so that they can be captured in a naturalist's trawl with a fine gauze-bag at the end. There is, therefore, a downward tendency as the little fishes get older and stronger, and thus in many cases a parallelism exists between them and the minute forms on which they prey, for on deposition the eggs rise towards the surface, where the helpless larvæ (or newly hatched young fishes) also often occur, and then they seek the lower regions of the water as their size increases.

There is much that is wonderful in such a life-history, especially in the metamorphoses or changes of form undergone by many of our best fishes such as the flat fishes (Pleuronectidæ), which come out of the egg just like a haddock or a cod, with an eye on each side, as in Fig. 1, yet in after life have both eyes on the same side. Nothing like this occurs in any of the higher vertebrates. Gradually during growth the body of the fish increases in depth (Fig. 14), then the right or left eye passes over (Fig. 15) the ridge of the head to the opposite side, while the creature, hitherto pelagic, sinks deeper in the water and exhibits a tendency to lie on the side from which the eye has passed, and which gradually loses its dark pigment so as to become white[1]. It finally reaches the bottom, taking up its residence amongst the sand or sandy mud, and lying with the two eyes and the coloured side up, the

Fig. 14. Young Lemon-Dab in the third stage, enlarged.

[1] The tardy disappearance of the pigment in some forms is interesting.

white underneath. At the same time they push inshore, and multitudes are found on muddy flats between tide-marks, and in shallow rock-pools, their bodies being immersed in mud, but the two active eyes raised above it. When disturbed, a little streak of muddy water alone tells their course. The mode by which the eye travels round has been a fruitful source of discussion with scientific men, and amongst these the names of Steenstrup, Malm, Schiödte, and Alex. Agassiz abroad,

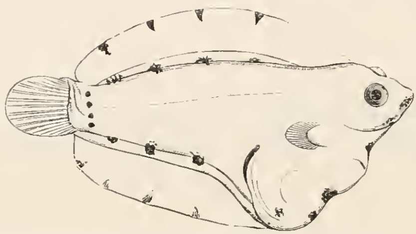


FIG. 15. Young Lemon-Dab at a later stage, the left eye just appearing on the ridge of the head: enlarged.

with Wyville Thomson and Traquair in our own country, are well known. The fact is—two methods exist in nature; in the one the eye travels over the ridge of the head, as just described in the flounder; in the other it traverses the soft and yielding tissues of the young fish, and so gains the other side. In *Plagusia*, the species in which the latter remarkable change occurs in the post-larval stage, the general tissues are so transparent that the creature in a glass vessel can only be noticed by the two apparently disembodied eyes, or by the gleam of light caused by its movements; and before the change ensues in its eyes it can look obliquely through its own body and see what passes on the other side[1].

Up to this stage in the life-history of both round and flat fishes it will have been apparent that the efforts of man can have little effect on the vast multitudes of the eggs and minute fishes. His trawl sweeps beneath them, or they are carried harmlessly through its meshes. Not even in a trawl blocked by a fish-basket and several large skate are any likely to

[1] Alex. Agassiz, *Proceed. Americ. Acad. Arts and Sc.* vol. xiv. p. 8, 1878.

occur. No example indeed was procured in the trawling expeditions for the Commission under Lord Dalhousie. The hooks of the liners are too large for the mouth at this stage, and hence they escape capture. Their small size and translucency also seem to afford protection in the case of predatory fishes of their own or other kinds, for they are rare, so far as present observation goes, in the stomach of any fish. Their great numbers are doubtless kept in check by some means, and we know that even jelly-fishes (e.g. *Pleurobrachiæ*, Fig. 11) and sparrows are very fond of post-larval fishes. It is only when they become somewhat larger that they are preyed on by their own and other species, and are swept up in thousands by the destructive shrimp-nets on our sandy shores.

While the little food-fishes are assuming the change of hue indicated in the preceding pages, they in many cases seek the inshore waters; at least, systematic use of the mid-water and other nets prove that at certain seasons they are met with in large numbers at the entrance to bays or off-shore, and that a little later, in the case of the cod—from the first of June onwards, they are visible from the rocky margins. The coloration in this species (cod) is now beautifully tessellated (Fig. 5), and they swim in groups, often in company with the young green cod, at the margin of the rocks at low water, and in the little tidal bays connected with rock-pools. The latter are often richly clothed with tangles, bladder-weed, red and green seaweeds, and the green *Ulva*—amidst the mazes of which the young fishes find both food and shelter, capturing the little crustaceans (Copepods, Ostracods, and others) swimming there, and snatching the young mussels and minute univalve mollusks from the blades of the seaweeds. To the zoologist few sights are more interesting than to watch the little cod in these fairy lakes, as they swim in shoals against the current, balancing themselves gracefully in the various eddies by aid of their breast-fins. In a mixed company, the young cod are easily recognised by their coloration, and the reddish hue of the occiput, for the blood-vessels there shine through the tissues, which generally are more translucent than in the green cod.

Prof. G. O. Sars considered that about this stage there was an intimate connection between them and the hordes of jelly-fishes (*Aurelia* and *Cyanea*) which abound in the inshore waters towards the end of summer. He thought the young cod approached the jelly-fish for the sake of the minute pelagic animals stupefied by its poisonous threads, and that the fish repaid this favour by picking off a parasitic crustacean (*Hyperia medusarum*) which clings to the jelly-fish. Observations, continued for a long period in this country, however, show that this connection is only casual and of very little importance, and that certain *Hyperiæ* are occasionally found in vast numbers in a free condition.

As the season advances, the young cod are joined off the rocky ledges by a few pollack and whiting, but not by the haddock, which has certain social views of its own—keeping to the deep water farther out. The size of these cod late in autumn, as in October, varies, some reaching from 4 to 5 inches in length. Their food ranges from zoophytes to crustaceans, mollusks, and small fishes, and in confinement the larger are voracious, an example in the laboratory about 5 inches readily attacking a smaller (3 inches) and swallowing it as far as possible, though for some time a considerable portion of the body and tail of the prey projected from the mouth. Moreover, the tessellated condition becomes less marked, and as they approach 8 inches in length a tendency in some to uniformity of tint is noticeable. Many of those, however, that continue to haunt the rocky shores and the tangle-forests beyond low water still retain for some time mottled sides, and they are known by the name of rock-cod. Further, while their growth in the earlier stages is less marked, it is now very rapid—even in confinement. The exact rate of growth in the free condition in the sea is difficult to estimate, but the little cod of an inch and a half to an inch and three-quarters in June reach lengths varying from 3 to 5 inches in autumn, and in the tanks of the laboratory, specimens 5 inches in August attain 8 inches the following March. At Arendal, in Norway, where opportunities for watching the growth of cod in confinement have been supplied with a liberality not excelled in our country, Capt. Dannevig found that the cod of 3 mm. in April reached only

15 mm. in June, a length somewhat at variance with the condition, as above stated, on our shores. In July they measured 2 inches, in September 3 inches and a half, and in October about $4\frac{1}{2}$ inches. The second year they attained 14 to 16 inches in length. In artificial circumstances, as well as in nature, it is found that great variation exists in the sizes of the young fishes of the same age, and this variation would not seem to be related to temperature.

At the stages just mentioned they now come under the notice of both liner and trawler, for young cod 5 or 6 inches in length occasionally take a haddock-hook, and those somewhat larger (9 to 18 inches) occur in certain hauls of the trawl, especially off a rocky coast like that of Aberdeenshire, south of Girdleness, as well as on the hooks of the liners on rough ground. Special trips, indeed, were, and perhaps are, made by the liners for the capture of these young cod (termed codling), and thus their numbers are kept in check.

So far as present observations go, therefore, the young cod in a free condition reach the length of from 4 to 10 inches the first year, while in the second they attain from 10 to 20 inches or more. It probably takes 3 or 4 years (and this is the original opinion of Sars) or more, to reach full maturity and a length of 3 feet or upwards; though he mentions having seen young cod a foot in length, with mature roe and milt in the fish-market of Christiania. These, however, were probably examples of the small race of cod characteristic of the fjords of Norway.

The young round fishes, such as cod, haddock, and whiting, of similar or nearly similar size, seem respectively to herd together. Thus it happens that in certain hauls of both liners and trawlers the majority agree in size. This is well known to the liners, who in former days specially sought out the young cod as already indicated. The same feature is observed in many other fishes, and probably conduces to their safety.

So far as known, the adult fishes of the three kinds specially alluded to in the preceding paragraph (viz., cod, haddock, and whiting) follow no very definite law in regard to migrations, if we except the apparent congregation in certain regions during the spawning season, as pointed out for instance by Sars, off Lofoten, where they occur in vast numbers from January to March. In our own country, again, the appearance of shoals of haddocks and whiting in certain localities is another example. How far such multitudes, however, are influenced by the abundance of food is still an open question. In British seas the herring is the main cause of these congregations of cod and haddock; the former chiefly pursuing the fishes, the latter their eggs. In the same way, the abundance of Norway lobsters and similar food on the grounds called banks exercises considerable influence on the presence of cod.

It has already been pointed out, however, that in their young stages certain migrations do occur. Thus the post-larval cod by-and-by seeks the laminarian region, while the older forms for the most part tend to go seaward. The haddock keeps to the deeper water in its post-larval and very young state. The same occurs even in a more pronounced manner with the ling, the adults of which as a rule are found in deep water. The pelagic post-larval ling seeks downwards as it grows, and is seldom found near the shore till it attains the length of six or seven inches, in short, until it is barred with pigment. As it increases in size it migrates seaward. Similar features are noticed in the plaice. As observed in the trawling expeditions of 1884, only large plaice as a rule are procured in deep water off the east coast, while the sandy bays abound with those ranging from 11 inches downward, and none of the females of which appear to be mature. Multitudes of little plaice haunt the margins of these sandy beaches, but it cannot be said that forms which have the length, for example, of 3 inches, are confined to any particular line drawn across a bay, for small forms (2–4 in.) occur in hauls all over such a bay as that of St Andrews. Small turbot and halibut in the same way are often found in the shallow bays, while the large adults are inhabitants of the deeper water. Such would not, however, seem to be the case with certain skate, very large adults of which occur in the shallow water of the sandy voes in Shetland.

On the other hand, the witch (*Pleuronectes cynoglossus*) keeps to its special areas, both as regards the young and the adult condition, so that the movements of eggs, larval and post-larval forms are circumscribed; and the same, to some extent, would seem to be the case with the topknot (*Zeugopterus*) and sail-fluke (*Arnoglossus*). The dab (*Pleuronectes limanda*), again, is found in all stages both in comparatively deep and in comparatively shallow water.

Almost all our valuable food-fishes, therefore, are produced from minute pelagic eggs, the enormous numbers of which provide for a vast increase and wide distribution of the species; yet it cannot be said that this habit alone provides for their multiplication when the case of the herring with its demersal eggs, fixed firmly to the bottom, is considered. It has to be borne in mind, however, that the larval herring mounts upward toward the surface as soon as its strength suffices.

Many striking changes occur during growth, both in external form and coloration, but it is difficult at present to lay down any general law that would apply to all cases, though those in which certain migrations take place during growth show such changes very prominently. The young round fishes by-and-by roam about the sea in shoals, led hither and thither mainly by the presence of food; yet in the case of the larger and adult forms, safety or freedom from molestation may have some influence. Though so minute on escaping from the egg, their growth is, by-and-by, rapid, and the duration of life in such as the cod is considerable. Abundance of food, more than any special instinct, would appear to be the main cause of their migrations in the adult or adolescent state, and that food is as varied as their haunts; in short it embraces every sub-kingdom up to their own, for fishes and their eggs form a large share of their diet.

There would be little difficulty in adding to the sea great numbers of larval forms of any species of which eggs can be procured: yet if a few adults can be obtained in such waters at the proper season it is still an open question whether the natural process with its surroundings would not be more successful.

In the foregoing remarks a few of the leading features of the life-history of a food-fish have been but touched on, for the subject is one of vast extent, and some of the points embraced in it are by no means easily solved. We have only earnestly entered on the study of the subject in this country within the last few years, and much yet remains to be done, even in some of the most common marine fishes. However, the zoological investigator is here stimulated by the fact that all his labours directly bear on the public welfare, for it need hardly be pointed out that a thorough knowledge of the development and life-histories of our food-fishes is the first step to sound legislation and effective administration. The State has in past years spent princely sums on more or less pure science, as in the memorable voyage of the *Challenger*. There can be no doubt, notwithstanding the recent opposition, that at the present moment the public interests demand a searching and long-continued inquiry nearer home, viz. the exhaustive investigation of all that pertains to the food-fishes of our shores, since the problems connected therewith affect the prosperity of so large a portion of the population.

The difference between the larval cod and the young salmon just hatched is striking. The former, that is, the young cod, is in a very rudimentary condition, not only in size but in structure. For instance, it is devoid of mouth and vent, and though the heart pulsates, it, as our colleague, Prof. Pettigrew, observed, is devoid of blood, and there are no blood-vessels. Those, therefore, who thought that the heart in animals contracted from the stimulus of its living blood, would have here found little support. The tiny larval cod of about 4 mm. is so fragile that it can be handled with difficulty, and it would seem as if a breath would destroy it. On the other hand the newly-hatched salmon has attained great complexity, and is about three-fourths of an inch in length, while several days may be spent in delineating its elaborately branched blood-vessels—through which the blood-discs may be followed as they swiftly circulate in the transparent tissues.

CHAPTER V.

GENERAL SKETCH OF MARINE TELEOSTEAN DEVELOPMENT.

In a work like the present it is unnecessary even were it practicable to give in detail all the authors who have laboured in the field, or to enter into narrative in regard to the type taken to represent the development of the food-fishes.

Lists of those who have made advances in the development of these fishes will be found in the various treatises and monographs on the subject. In the list appended to the *Researches*, by one of us and Professor Prince, no less than 160 authors of importance are cited in 1889, and the list has considerably increased since.

It will suffice if a brief and somewhat popular *résumé* be given, firstly, of the changes which are externally visible in the egg up to the period of hatching, and secondly, of some of the leading structural changes at various stages, mainly followed out by the systematic study of sections.

For illustrating the changes undergone by such an egg floating about in the sea, we shall take the translucent pelagic egg of the whiting (Fig. 16) in the month of April, and it may at once be stated that it forms a very good type for almost all the bony fishes. As discharged by the adult on the spawning-grounds the translucent sphere consists externally of a hyaline capsule, which under a high power is observed to be minutely punctured, and under certain conditions has a tendency to break into film-like scales of membrane.

It really consists, however, of a single layer and is not compound as some authors have supposed.

At one part of the capsule a minute indentation (micropyle) is seen leading to the interior, and this aperture has various shapes in different fishes (Fig. 19). Fluid is readily transmitted through this entrance, and also by the pores—as may be seen by partially drying the egg, and then immersing it in sea water—a feature connected with the aeration of the contents.

Within the capsule we have the globe of more or less fluid yolk or nutritive material—surrounded by a delicate layer of protoplasm, between which and the capsule is a space termed the perivitelline space. The entire egg of the cod or whiting (Fig. 16) is a transparent spherical floating mass

Fig. 16. Egg of Whiting, with cap of protoplasm. E. E. P.

delicately sensitive to every movement in the water, even a breath in a still vessel setting the almost invisible spheres in commotion; so that under the microscope even in a quiet room, and still more in a wooden building, we may understand it is not always easy to keep them in the field of vision.

In the spawning-areas, at the period of the shedding of these eggs, the water swarms with the minute sperms of the male, one of which, in the course of events, finds entrance by the aperture (micropyle Fig. 19 *a*) in the wall of the egg, and then begin those changes which mark fertilisation, such as the fusion of the male with the female pronucleus, the protrusion of the polar globules and the formation of the first segmentation-nucleus.

Shortly after fertilisation the egg in many cases becomes more tense and the space within the capsule, the "breathing chamber" of Needham, more evident.

In the cod and others, moreover, a streaming movement of the jelly-like protoplasmic covering of the yolk downwards, towards the animal pole, takes place. At this pole, always on the lower side of the floating egg, the protoplasm collects, forming a faintly straw-coloured cap in which granules are scattered (Fig. 16). At this part the first segmentation-nucleus may be seen.

Soon after the appearance of this cap, e.g. in 40 minutes in the whiting, longer in the cod, an indentation begins in the middle which gradually deepens until the cap is bisected (Fig. 17). Thus, instead of one, two segments are now present.

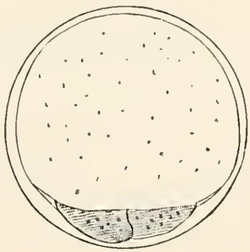


Fig. 17. Egg of Whiting. Commencing segmentation. E. E. P.

In a similar manner the splitting proceeds in each of these, resulting in the formation of four segments, and these again are subdivided by bisecting lines, so that eight segments result.

This process is continued with considerable, but by no means absolute, regularity. In the colder months during which these changes take place in the cod it is a much slower process than for instance in the whiting, which at a later season develops more rapidly.

In other words, the rapidity of segmentation is directly dependent on the temperature. Thus the egg of a whiting, observed by Prof. Prince, which showed at 6.40 the first furrow, presented at 9 p.m. the accompanying changes (Fig. 18, *a*, *b*, *c*, *d*, *e*)—the last stage (*e*) having the specks or nuclei in the segments.

Thus the whole disc, passing from the 8 to the 16, 32 and higher stages, at last forms a finely divided cap (often termed the blastoderm), which is now said to be in the many-celled stage; this is reached on the second day. The whole process of segmentation thus consists of the dividing up of the protoplasmic cap into a number of cells, each containing its nucleus and enveloped in its cell-membrane (Figs. 19 and 20, surface and

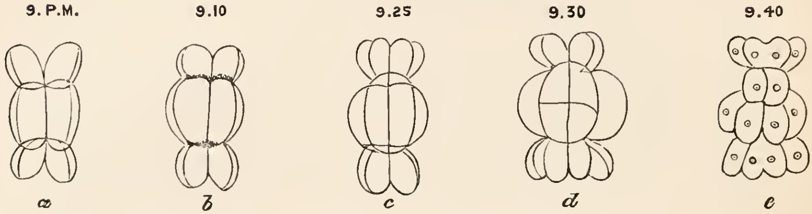


FIG. 18. Egg of Whiting. *a.* View of segmenting blastoderm, 9 p.m. *b.* View of segmenting blastoderm, 9.10 p.m. *c.* View of segmenting blastoderm, 9.25 p.m. *d.* View of segmenting blastoderm, 9.30 p.m. *e.* View of segmenting blastoderm, 9.40 p.m. E. E. P.

lateral views). Moreover, surrounding the disc, which in lateral view soon becomes lenticular or lens-shaped (Fig. 20), is a ring of small pinkish dots or nuclei, in the protoplasmic belt or

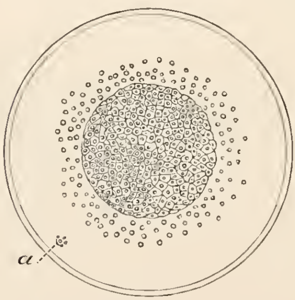


FIG. 19. Egg of Cod. View of many-celled blastoderm from above. E. E. P.

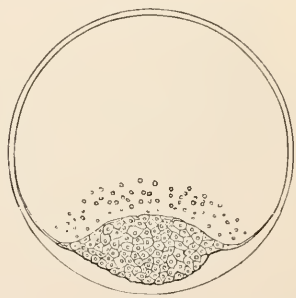


FIG. 20. The same. Egg of Cod. View of blastoderm from the side. E. E. P.

periblast, forming the so-called nuclear zone. This is more clearly seen in the highly magnified portion of the edge of the disc in Fig. 20 *a*. The nuclei have a central speck or nucleolus.

16*th April*, 2*nd day*. Next day it was found that at 9.30 a.m. the disc of the egg presented little change, except that the nuclei in the zone surrounding it were more numerous. This nuclear zone became less distinct at noon and about 1 p.m. it had all but disappeared.

17th and 18th April, 3rd and 4th days. When segmentation is complete the blastoderm undergoes a change of a striking character. It becomes raised and separated from the yolk so that a chamber, not coincident with the centre of the disc, is formed between its under surface and the yolk (Figs. 21 and 22, surface and lateral views). This chamber,

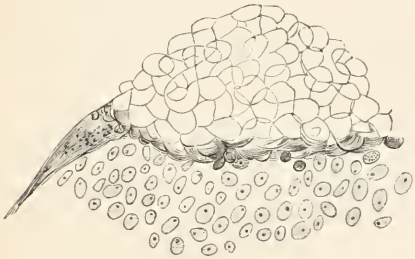


Fig. 20 *a*. Edge of blastoderm with nuclear zone (periblast). Highly magnified. E. E. P.

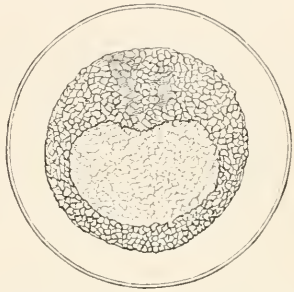


Fig. 21. Egg of Whiting with germinal cavity. Dorsal view. E. E. P.

usually termed the segmentation-cavity, has also been styled the 'germinal cavity' by Prof. Prince, to emphasise the fact that it differs in some respects from the segmentation-cavity of other types of vertebrate animals.

The blastoderm at this stage shows no clear differentiation into layers, though the upper stratum is usually distinguished as a layer of ectoderm or epiblast-cells, and that below, forming the main mass, as the lower-layer cells.

A new series of changes now ensues. Formerly, in the

Fig. 22. Egg of Whiting with many-celled blastoderm and germinal cavity. Lateral view. E. E. P.

early ovum, the protoplasmic covering of the yolk tended to stream downwards and augment the disc, but now the blastoderm commences to grow up and over and to envelop the yolk (epiboly, Fig. 22). With the commencement of this process the blastoderm flattens, and the vertical height of the germinal cavity is reduced to form a mere fissure, whilst the germ becomes generally thinner, yet along one radius there is a distinct cellular thickening, viz. the embryonic radius (Fig. 21), and this is noticed many hours before the inflection of the inner layer or hypoblast, which will be mentioned later.

When the blastoderm covers about a quadrant of the globe of the yolk, the rim or border is visibly thickened, forming, as some authors name it, 'a true pad around the egg.' This curious condition is usually explained thus:—the amount of yolk prevents the formation of an ordinary 'embolic gastrula'-stage in this case, hence the yolk has to be enveloped by growth of the blastoderm over it.

At this stage we may glance at the formation of the yolk (deutoplasm) in such eggs. As a rule in pelagic eggs, the yolk is a transparent homogeneous liquid through which a body like an oil-globule, such as occurs for instance in the gurnard, freely passes. In the earlier stages a different condition prevails: thus in the roe or ovary the developing yolk is quite opaque, composed of a number of spherules with intermediate protoplasm, as seen for example in the early ovum of the turbot (Plate III., fig. 22). In such species as the cod, the yolk-mass clears up before ripening, and the protoplasm collects mostly on the surface, but that all the protoplasm is thus removed is not yet proved. For instance, in some cases collections of protoplasm take place on the yolk after the closure of the blastopore. In some eggs, as in that of the sole, a vesicular condition of the surface of the yolk is caused by evident strands of protoplasm cutting off portions of yolk, and in the herring-tribe and murænoids the whole yolk is thus divided.

The transparent condition of the yolk is not found in the demersal eggs and it is probably to be regarded as a special protective adaptation to a pelagic habitat; the pelagic fauna, consisting of examples from most of the leading groups of animals, are as a general rule characterised by transparency of the tissues.

The yolk forms a store of nutriment which is little used in the earlier stages of development, though there is no reason to suppose that it is altogether inert, since the neighbourhood of the layer of protoplasm separating it from the blastoderm is a scene of considerable activity. In the later stages the rapid shrinking of the yolk before the embryo leaves the egg shows how important it then is in affording nutriment for the development of the embryo.

All the changes are not readily seen without making sections of the prepared eggs, especially as regards the origin of the second primary germ-layer (hypoblast). Its exact derivation has given rise to much speculation, but it would appear mainly to arise as an infolding and ingrowth of the outer-layer cells (epiblast), supplemented by periblast-cells. This folding is seen at a very early stage, and after the disc has flattened out it can be followed to the central region of the animal pole, a region which corresponds with the embryonic thickening formerly mentioned. The effect of this ingrowth of cells is that the originally very definite outline of the embryonic shield becomes irregular and finally disappears or passes imperceptibly away on all sides, except posteriorly.

A typical section of a teleostean egg (e.g. that of cod) when the yolk is about half-covered by the blastoderm shows a single layered corneous outer stratum and beneath it a thicker mass of cells, the former being the outer and the latter the inner layer of the epiblast. Another layer of cells, the hypoblast, borders the embryo towards the yolk. The third primary layer, or mesoblast, has yet to be described. It arises in great part from the lower-layer cells, that is, those seen very early under the epiblast, and probably also in great measure from the hypoblast, and the cells so derived soon become divided into longitudinal sheets or masses. These three primary layers are clearly distinguished in the early embryo, except at the extreme hind region, in which they are all confluent in a mass of indifferent cells. At the extreme head-end, on the other hand, there is still only epiblast and hypoblast, as the middle layer does not extend into this region till later.

As the rim extends over the yolk the embryonic shield lengthens, the keel thickens, and soon a spathulate flattening of the central or nervous layer is noticed anteriorly, that is, at the opposite end from the aperture of the blastoderm (the blastopore), the spathulate process trending posteriorly to the margin of the aperture. Then differentiation of the spathulate region (Fig. 23) occurs by the definition of the optic vesicles from the solid cellular margin (Fig. 24). Very soon after the formation of these organs traces of the ears appear

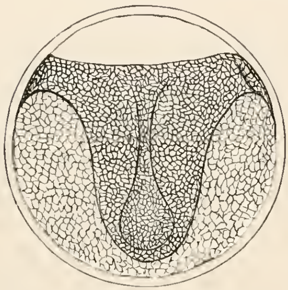


Fig. 23. Egg of Whiting with spathulate neurochord.

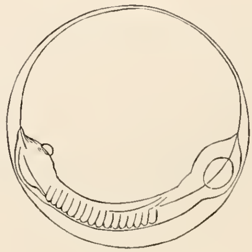


Fig. 24. Egg of Cod with embryo. Lateral view.

more posteriorly, as elongated or elliptical thickenings of the sensory layer of the epiblast, and a large fissure or chink develops in the centre.

To return to the growing blastoderm as it covers the yolk, it is found that the thickened margin or rim bounds an aperture called the blastopore by embryologists, this aperture attaining its maximum when the margin of the blastoderm has reached the equator, and thereafter decreasing in calibre as the rim advances towards the vegetal pole of the yolk (Fig. 23); the latter indeed in certain views bulges from the rim like an india-rubber ball pressed in the fingers. The embryonic rim is used up in the formation of the embryo.

The aperture or blastopore then becomes contracted, marked with radial lines or furrows, and finally closes.

In eggs with oil-globules it is at this time that the globule becomes surrounded by the protoplasmic periblast-layer which envelopes the yolk. Only in one instance, and that probably abnormal, has the globule been found freely moveable in the larval yolk-sac after hatching, viz. in the torsk or tusk[1]. Moreover, black pigment at a somewhat later stage develops in the periblast bordering the yolk.

We may further note that in demersal eggs with vitelline circulation, the germinal cavity disappears, after closure of the blastopore, partly by the pushing in of mesoblast.

When the blastopore closes, or a few hours before, a vesicle (Kupffer's) appears on the ventral aspect of the embryo slightly anterior to the tip of the tail (Fig. 24). Occasionally other vesicles occur along the under surface of the embryo, in front of the foregoing.

At the same time, a canal (neurenteric canal) is seen passing, from the transient homologue of the medullary groove of the dorsum, to the under surface of the embryo. In most other vertebrates, the groove in the dorsum, called the medullary groove, which closes later to form the canal of the spinal cord, is a very early feature in development, whereas in the cod and other Teleosteans the solid mass forming the spinal cord has a fissure formed in its axis only at a later date. In the same way the neurenteric canal and blastopore are much more conspicuous features of the larval stages of other vertebrates.

19*th April*, 5*th day*. With the closure of the blastopore, the definition of the embryonic fish as an elongated rod pressing into the surface of the yolk, becomes marked. The middle layer or mesoblast has by this time segmented into five or six transverse divisions called muscle-plates or protovertebræ. The primary axis (notochord) can be traced some distance forward, but only as a broad translucent streak. This organ arises from the hypoblast as a median axial rod of cells growing upwards and separating the two rows of mesoblastic lateral protovertebræ. These increase in number rapidly, so that with the extension of the mesoblast forward, the trunk is wholly segmented, and they give the embryo a transversely banded appearance. On either side of the head an invagination of a small area of epiblast gives rise to the lens of the eye, and an expansion of the lateral walls of the embryo on each side forms what is called the alar membrane.

[1] W. C. M. 10*th Ann. S.B.F. Rep.*, p. 290.

The heart is formed of a solid and rounded projection of the middle layer bulging out towards the subjacent periblast.

20th April, 6th day. The brain is now differentiated into fore-brain, mid- and hind-brain (Figs. 25 and 26). The lens

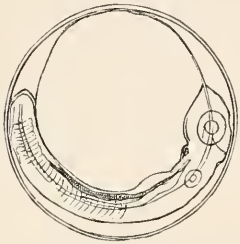


Fig. 25. Egg of Cod with embryo on 6th day. Lateral view.

Fig. 26. Egg of Cod with more advanced embryo on 6th day. Ventral view.

of each eye is complete, and otoliths have appeared in the otocysts. The heart assumes a conical tubular appearance, and the inner layer (hypoblast) has formed the gut, in which a cavity is now apparent—large in the median region, and tapering to the solid anterior part. The liver appears as a blind diverticulum of the gut, on the right side in most views. The otocysts are more ovoid in shape, and the notochord reaches forward to them. It has a downward flexure at its anterior end and shows signs of vacuolation. The third pair of sense organs, or nasal pits, is now indicated. Three diverging lines on the ventral surface of the brain indicate the lateral ventricles.

The pectoral fins are outlined, and delicate protoplasmic

Fig. 27. Egg of Cod with embryo on 9th day. Nearly dorsal view.

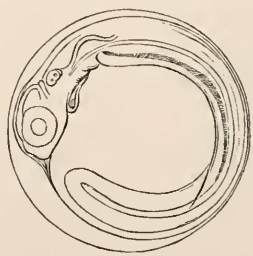


Fig. 28. Egg of Cod with embryo on 9th day. Lateral view.

expansions stretch out from the body in front of them on the yolk.

21st April, 7th day. The body is now jerked from side to side by the contraction of the trunk-muscles, and has lengthened; the caudal extremity is flexed (Figs. 27 and 28). The ear-capsules or otocysts, although they arose in a position behind the head, have now moved forward towards the eyes. The heart forms a long cone with the open end to the left, and debouching into the germinal cavity, while the apex passes to an expansion in the mid-region.

The heart beats languidly and irregularly, the pulsations sometimes ceasing for 15 or 20 seconds. The gut is hollow as far forward as the heart. The primitive axis, or notochord, is now completely crossed by intermingling arcs.

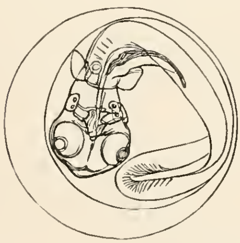


Fig. 29. Egg of Cod with advanced embryo (9th day).

Fig. 30. Egg of Cod with advanced embryo.

22nd April, 8th day. The posterior regions of the trunk and tail are flexed, and the yolk has considerably decreased. The continuous median marginal fin is now in evidence, and the

Fig. 31. Egg of Cod with more advanced embryo. Lateral view.

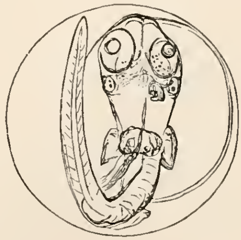


Fig. 32. Egg of Cod with more advanced embryo.

pectoral fins are well defined, rounded anteriorly and pointed posteriorly. The liver (arising from the ventral region of the gut) forms a rounded process. The heart has a trumpet-shaped venous end and a boldly flexed arterial portion. The pulsations are now more regular—about 25 per minute. Rounded black chromatophores, or pigment-cells, have appeared on the head and dorso-lateral region of the trunk, but they have no regular linear disposition (Figs. 29—33).

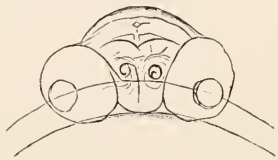


Fig. 33. View of the head of the same embryo from the front.

23rd April, 9th day. By this time the eyes become pigmented with rounded black chromatophores and the pigment-spots of the body and tail are more numerous. Three branchial clefts have made their appearance behind the ears. The olfactory bulbs are connected with the nasal pits. The liver has acquired an irregular lobulated appearance, and the gut is a prominent vermiform structure (Fig. 34).

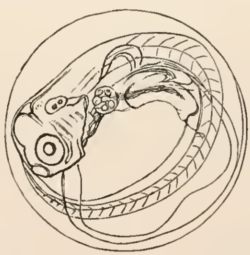


Fig. 34. Nearly lateral view of an embryo of the Cod on the 9th day. Almost ready to hatch.

The violent wriggling of the embryos indicates their advancement, and a few issue from the eggs this day. The empty capsules retain their spherical shape though a lenticular rent passes two-thirds across their diameter (Plate III., fig. 2).

24th April, 10th day. Five-sixths of the embryos are still in the eggs. They present a similar appearance to those of the previous day, though the increasing complexity of the gill-region is evident, and four clefts are visible, extending outwards to the otocysts.

The heart is larger and the two chambers are more distinct.

25th April, 11th day. Black pigment-spots are sparsely scattered over the dorsal and lateral regions and a few on the tail.

The eye has a bright bronze hue.

The remainder of the embryos emerged on this day.

The subsequent changes are best described under the special head of each organ, so that we have now to retrace our steps and observe what is the history of the various organs we have mentioned. These organs may be classified according to their origin from each of the three primary layers of the germ, namely, the outer layer or epiblast, the middle layer or mesoblast, and the inner layer or hypoblast. They are most conveniently described under these heads.

Organs derived from the Epiblast or Outer Layer.

Nervous system.

We have seen that the outer layer or epiblast was established as a single layer of cells in the developing disc or blastoderm. These cells early become flattened and in section spindle-shaped. The outer or corneous layer at first covers the trunk of the embryo and the arc of the blastoderm beyond, but later, cellular thickening occurs beneath—forming the nervous layer of the epiblast. We have, indeed, seen that this thickening forms the keel (carina) that presses on the yolk. It becomes the rudiment of the spinal cord (neurochord). Its constituent cells are full and rounded but, as downward proliferation proceeds, those forming its lateral borders become columnar and unmistakeably mark off the neurochord from the adjacent cells, especially anteriorly. In the latter region they proliferate so rapidly, ventrally and laterally, that they come into contact with the inner layer or hypoblast and thus leave little room for mesoblast. Both layers of epiblast seem to extend over the yolk-sac. It is below the second layer that the pigment-corpuscles occur.

The enlarged anterior part of the neurochord forms the brain. It is rounded above, deeply carinate below, arched over by the epiblastic integument and limited ventrally by the hypoblast. From the anterior region of the brain, or fore-brain, grow out the paired optic vesicles, and the mid-brain is easily distinguished by its greater breadth and volume. Immediately posterior to it is the hind-brain which passes into the neurochord. It is remarkable that the brain forms nearly $\frac{1}{3}$ of the total length of the embryo in its early condition.

When a quarter of the yolk is enveloped, a cleft appears on each side of the post-optic region.

One anterior portion, the united mid- and fore-brain, can now be distinguished from the hind-brain, which is soon separated by a similar slight fold from the spinal cord behind. The mid-brain, lastly, is constricted off by an interorbital fold and the three regions become clearly defined.

Instead of the medullary folds in the other vertebrates, which close together and form the spinal cord with its median cleft (neural canal), we have in these bony fishes a solid mass or rod of cells forming the neurochord, which later acquires a cavity by a separation of the median cells. In some Teleosteans, for example the gurnard, a remnant of the medullary groove is seen in the deep temporary groove in the dorsal surface of the neurochord about the fourth day—whilst still in the egg.

In the cod, soon after the closure of the blastopore, a fine cleft appears by separation of the median cells in the brain along a vertical longitudinal plane. It commences in the mid-brain and thence extends into the fore-brain almost to the anterior limit of the latter. This is the first indication of the true neural canal. Then two lateral continuations form a cruciform fissure, marking off the fore-brain; whilst a T-shaped lumen is found in the mid-brain, the roof being thinner than the walls or floor. The canal rapidly extends into the neural cord in the trunk, giving off a pair of (vertical) lateral cavities, forming the optic ventricles and *iter a tertio ad quartum* *ventriculum*, and a median pair constituting the fourth ventricle. Several days before escaping from the egg, great extension of the mid-brain occurs.

On hatching, the mesencephalon (optic lobes) embraces the largest extent of the brain, and gives it the bulbous form so characteristic of young Teleosteans. The cerebellum is almost entirely covered by the posterior enlargements of the optic lobes, a thickened ridge only projecting. The fore-brain forms a narrow laterally compressed mass with a small dorsal chamber. On the second or third day after hatching, a deep fold divides this into anterior fore-brain (or cerebrum) and posterior fore-brain (or thalamencephalon), in addition to the longitudinal fold formerly present.

Very early a posterior part of the floor of the thalamencephalon is directed backwards as a prolongation beneath the elevated *medulla oblongata*, and at the same time obliquely downwards. The cells surround a cavity continuous above with the third ventricle, or cavity of the thalamencephalon. This is known as the infundibulum, which abuts on the roof of the oral cavity. A loose mesh-work of cells lies behind the infundibulum and into this the front end of the notochord pushes. On the summit of the arch caused by the elevation of the oral roof a mass of cells appears, proliferating from the oral roof-cells. This is the pituitary body (hypophysis) and it lies in front of the infundibulum. A small median swelling, not unlike the hypophysis, lies in front of the other, i.e. behind the point where the optic nerves cross. Such appears to form the inferior lobes (hypoaria), so well developed in Percoids.

The small extent of the roof of the thalamencephalon exposed becomes very thin and much folded. In sections there is seen a central aggregation of cells, which later push out as a papilliform process, containing a cavity which is continuous with the third ventricle below. The cells become columnar and it forms the pineal 'gland.' It becomes truncated, more or less plicated and pressed against the arachnoid membrane. Later still its lumen is obliterated and it forms a deeply folded mass of cells.

The spinal cord, when fairly advanced, proceeds quite to the termination of the notochord posteriorly. Usually the terminal part is attenuated, but occasionally it is slightly enlarged.

Eyes. (*Optic nerves and vesicles.*)

One of the earliest features in the embryo is the great development of the cephalic region, which is chiefly due to the protrusion of two rounded lateral masses (optic vesicles) from the sides of the narrow fore-brain. This cellular proliferation later shews a median slit, the only approach to the hollow brain-vesicle in the primitive forms. This slit passes along the stalk into the fore-brain; and subsequently it is seen that the optic nerves are at a different level.

Very soon the vesicles become cup-shaped by the pressure of an almond-shaped mass of thickened epiblast—the future lens, and the thinner margin creeps over the intruding mass of epiblast so as to form a circular lip around it, except at the lower side. The gap thus formed is called the choroid fissure and persists for some time. Mesoblastic cells, which were included as a thin plate between the optic nerve and the brain, have spread over the front as an outer layer (sclerotico-choroidal sheath) and pushed their way through the choroidal fissure into the internal chamber of the eye, and probably break down to form the vitreous humour and other structures. Just before hatching, pigment occurs outside the optic vesicle and in the external investment. Moreover, no less than six layers of the retina are present before extrusion occurs[1].

After hatching, the complexity of the eye is greatly increased, one of the most marked features being the development of well-defined rods and cones. The brilliantly opalescent iris not only adds to the remarkable appearance of the transparent larva but, with the pigment of the choroid, generally enables it to be discerned in the tanks.

Auditory organs.

The ears (otocysts) are formed, soon after the differentiation of the optic vesicles, as solid proliferations of the sensory layer

[1] Those specially interested should refer to Dr Marcus Gunn's account of the development of the Teleostean eye, *Ann. Nat. Hist.* Sept. 1888, pp. 263—268.

of the epiblast, considerably behind the latter organs. Then, in the radial arrangement of cells, a cavity appears; and this at first, in most bony fishes, has the form of an elongated slit, then it becomes broader and finally rounded. The walls are originally very dense, but become thinner subsequently. Otoliths occur about the sixth day, small at first, afterwards as two, occasionally three, distinct rounded calcareous masses. The otocysts change shape—becoming like an oyster-shell. Sensory cushions and semicircular canals are later developed, so that in the post-larval fish the auditory apparatus becomes complex.

Olfactory pits and nerves.

The olfactory pits are distinguishable on the sixth day or thereabout, as paired thickenings of the sensory epiblast in front of the upper part of the hemispheres. Each soon forms a flat oval sac of slightly elongated cells. The nerves are minute proliferations of the wall of the anterior fore-brain, which coalesce with the proximal surface of the nasal pit. Each pit has at first a single opening, but later a slight promontory appears in the middle of each lip and in a few days a junction occurs. The bridge becomes broad and each aperture is surrounded by an elevated rim.

Cranial nerves.

The embryos are unfavourable for tracing the development of the third, fourth and sixth, but the fifth (Trigeminal) is a large nerve which springs from the upper lateral margin of the hind-brain at a late embryonic stage. Just as it emerges, it separates into several branches, the maxillo-palatine and mandibular, each having a large ganglion from which other twigs pass.

Behind the foregoing nerve, the seventh and eighth arise in close proximity, the auditory being posterior and exhibiting a large ganglion. Fibres from the former can be traced to the base of the third ventricle or more correctly, above the pyramids, whilst the eighth or auditory consists of thin fibres which emerge close to the surface of the medulla, just below the overlapping posterior part of the optic lobe.

The vagus or tenth arises by two roots, the first, which probably includes the fibres of the ninth, issuing from a point near the lateral summit of the *medulla oblongata.* It perforates the auditory cartilage and sends branches to the gill-arches and pharynx. The second part describes a curve and can be traced to the median region of the medulla below the floor of the fourth ventricle, and above the pyramids, part of its fibres having a more superficial origin. They form in front of the pectoral girdle a large double ganglion below and, to some extent, internal to the ear. Fibres pass, further, to the pharynx and branchial arches, and, from a smaller ganglion, pharyngeal and cardiac branches are given off.

Lateral sense-organs.

Generally one of these occurs on the top of the head just behind the eye, a second behind the pectoral fin, and one or two along the caudal region. Each consists of a somewhat elliptical aggregation of granular columnar cells from which a number of very fine palpocils project. A delicate nerve-filament passes from the apparatus to the muscular plates, and this shows a slight enlargement at its proximal end, and another as it approaches the sensory organ. In some instances, the latter is absent whilst the nerve is present. In the haddock, the facial region has numerous papillary sensory bodies, which have a similar structure, viz. lengthened spindle-shaped cells. In the gurnard also, on the snout, tubes with cushions of columnar epithelium and sensory hairs occur, and they communicate with the cushions.

Skin.

It has already been mentioned that in early embryonic life there is externally a flattened layer or corneous stratum of epiblast, and beneath it is the nervous layer. Soon after the notochord is defined, these layers extend as a distinct integument all over the embryo and its yolk-sac. The inner stratum at a late stage consists of several layers of rounded cells, the innermost part probably constituting a Malpighian layer. A sub-epidermal space is often present, especially in those reared in confinement. No true skin at first occurs beneath the latter, but pigment-corpuscles appear in it, the hues in the different species being described elsewhere. Beneath the former, and constituting the true skin, the mesoblast extends later; in this the scales are subsequently developed and burst through the epiblast. When pigment occurs over the yolk it develops in the periblastic covering. In the development of a pigment-spot, as a rule, a colourless corpuscle, often branched, precedes it. At a late stage iridescent plates occur in this layer.

The Fins. *Median Fins.*

The embryonic median fin arises as a minute fold of the outer layer (epiblast) of the embryo within a day or two of the closure of the blastopore. This becomes a broad membrane, which increases after hatching. Its thinness and transparency are remarkable. In section it consists of the two layers of the epiblast and a central fissure continuous with the sub-epidermic space, which is filled with a jelly-like lymph and gives passage to delicate nerve-strands to the sensory papillæ of the skin. In this continuous fold, as F. M. Balfour said, by local hypertrophy the permanent unpaired fins arise, but atrophy of the interlying membrane takes place during development. Certain parts also in early stages are characterised by remarkable increase of pigment.

Shortly after hatching very fine fibrillar lines appear in this continuous fin, commencing generally in the tail. They form at first granular tracts indefinite in outline, and unconnected with the axial skeleton. They are usually termed, after Ryder, embryonic fin-rays. The mesoblast at a later stage extends between the layers of the fin, and thus it is this layer which gives rise to the true rays, which appear in the cod as three dorsal and two anal fins. Each ray at first forms a slight opacity extending towards the free margin, and the intermediate membrane disappears by absorption. The development of a mesoblastic granular thickening, a short distance from the tip of the notochord of the larval tail, is the first sign of the permanent organ. The true rays form in the lower region of the tail, the whole generally pushing the notochord with the larval tail upwards, and giving it a characteristic bend or slope, the boundary between the permanent and the larval tail being marked by a notch.

In some fishes, as in the cod and the haddock, though the ventral thickening is most distinct, the tip of the notochord remains median, and rays develop on both sides of it, making a feather-tip.

Paired fins.

When the embryo is first outlined, an alar expansion, consisting of epiblast and hypoblast, resting on periblast, stretches away on each side along the whole trunk. No mesoblast apparently extends into it. Soon two flattened oval pads, consisting of a double fold of epiblast, are differentiated from the rest of the expansion. Then the outer border of the cell-mass (mesoblast) near the Wolffian ducts sends a process between the layer and spreads out radially, but does not quite reach the distal margin. The fin gradually becomes disconnected from the covering of the yolk-sac, the central mesoblast assumes a columnar character, and later towards the trunk a stout peduncle is formed, cartilage-cells are developed, radial structures appear and lastly pigment may be seen on its surface. The fin, moreover, leaving its primitive horizontal position, becomes more or less vertical. During the third week after hatching, the rotation of the fin has made it obliquely vertical, and then the basal attachment is placed almost dorso-ventral. Embryonic and permanent rays develop as in the dorsal fin. A pectoral bar appears on each side, the first part of the girdle, and then the various elements of the latter, as shown in a special research of Prof. Prince[1], are outlined.

The ventral fins of the lesser weever appear in the egg shortly after the pectoral, and from the same alar expansion, but as a rule, in the forms with pelagic eggs, the ventral fins

[1] "On the Development and Morphology of Limbs of Teleosteans." Glasgow, 1891.

only appear in the later post-larval condition as shown under the various species.

Organs formed from the Mesoblast.

Heart and circulatory system.

The heart in the Teleosteans here described develops at a very early stage—before the œsophagus is formed—as a cylindrical cellular process of splanchnic mesoblast in front of the pectoral region, that is, between the otocysts and the optic vesicles.

After the alimentary canal is defined and when about 24 muscle plates are marked off, the heart has a vermiform shape and is still solid. A fissure soon appears in the centre, and the heart becomes a simple tube, then muscular twitchings and finally pulsations occur (48 to 60 per minute). The cavity is lined by a single layer of cells, but no fluid is yet present.

Then the cardiac tube becomes conical, and a pericardial chamber is apparent, also formed from mesoblast. The heart next becomes L-shaped, the arterial end being median, the auricular passing off at right angles. The cardiac lining becomes papillose, and granules may occasionally be seen at the open end of the auricle which is in communication with a space—the germinal cavity. This cavity becomes indistinct after the closure of the blastopore but again becomes evident between the periblast and epiblast of the yolk-sac (periblastic blood-sinus of Cunningham). The latter author is of opinion that this cavity is theoretically no longer the segmentation-cavity, since it is on its inner or periblastic side partially lined by mesoblast-cells, viz. chromatophores from the periblast. Morphologically, it is homologous with the vitelline vessels of the salmon, and, similarly, is continuous with the auricle of the heart and shut off from the pericardium by a definite mesoblastic membrane.

Meanwhile vascular canals are in course of formation, the dorsal aorta being hollowed out of the mesoblastic cells above the gut and under the notochord, and two lateral venous trunks in the connective tissue external to each head-kidney. In the larval ling the large channel from the liver to the tail, containing numerous large round corpuscles, can be traced on the fourth day. The venous trunks in front of the pectoral fins send prolongations downward and communicate with the venous end of the heart, which at this time is directed upward and backward as a sinus venosus which receives the venous trunks (Ductus Cuvieri) on each side, the latter trunk receiving not only the cardinal vein but the jugular. Around the cardinal veins the cell-tissue of the head-kidney or pronephros grows.

Before the end of the first week after hatching a simple circulation can be detected. The anterior bulbus and ventricle of the heart drives the blood upwards behind the eyes, probably by the artery of the hyoid arch, and along the dorsal aorta to the root of the tail, there it forms a loop and returns by a large venous trunk which anteriorly splits into the two cardinals. A day or two later a venous branch, the sub-intestinal, leaves the sub-vertebral vein and passes to the lower side of the gut along the margin of the liver to the sinus venosus. The intestinal artery (cœliaco-mesenteric) has a much longer course, for it leaves the dorsal aorta in the posterior region, traverses the mid-gut in descending, then courses beneath the rectum, ascends before reaching the vent, and passes along the anterior margin of the urinary vesicle to join the cardinal vein. In a cod of the seventh day the aorta and vein reached nearly a quarter the length of the cardinal trunk, while on the fourteenth day they extended almost to the tip of the tail. As was observed in the salmon many years ago by one of us the force of the current seems to hollow out the yielding channel. During the second week there are two gill-arches and sometimes three, which have developed arterial channels, and another vessel, the hyo-opercular artery. The mandibular courses along the ventral margin of the mandible, the vessels of opposite sides meeting and returning by a single vein. In the cod, when the caudal artery extends $\frac{2}{3}$ the length of the tail, four branchial arteries are visible, and a sub-maxillary artery beneath the eyes, whilst a return current is directed over the eyes by the supra-ocular vein. The vessels of the abdomen—

especially the veins—have largely increased, and the portal system is indicated. The proximity of the yolk to the great vessels returning to the heart makes it probable that these are connected with its absorption. As the absorption of the yolk takes place, however, before any circulation occurs, it is possible that the open end of the heart takes in the yolk-materials, as Mr H. C. Williamson has recently more clearly pointed out.

The origin of the blood-corpuscles is still open to discussion, more than one mode of origin being suggested. Briefly the formative elements of the blood seem for the most part to be derived from the periblast, the primary corpuscles being moulded from the detached cells of the sub-notochordal trunks.

Renal organs.

Soon after the splitting of the mesoblast into an outer layer (somatopleure) and an inner layer (splanchnopleure) a rod of cells is budded off from the latter. In the transparent pelagic forms, e.g. the cod, we find that a solid cylinder appears on the outer margin of the intermediate cell-mass, and it rapidly develops forward to the pectoral fins, but advances posteriorly more slowly. A lumen is formed by a radial arrangement of its cells. Thus a pair of simple ducts, whose walls consist of a single layer of columnar cells, originate from the pectoral region to the root of the tail. Anteriorly each tube, widely separated from its neighbour, is folded on itself inwards towards the notochord, and ends in a trumpet-shaped infundibular opening. Posteriorly the tubes approach each other and coalesce into a single tube, which at first is of small capacity with thick walls. Somewhat superficial at first, the ducts lie later ventro-laterally to the notochord and ultimately protrude into the peritoneal cavity. A connection is established posteriorly, at the urinary vesicle, with the cavity of the hind-gut. The crozier-shaped loop at the anterior end has in front of it a mass of trabecular tissue in which tubules appear to some extent to enter, but it is also penetrated by the basilar plate of the skull. Such is the condition of the pronephros or head-kidney at the time of hatching.

When the young fish emerges, the folds of the loop in front increase in complexity and a vascular glomerulus is developed near each trumpet-shaped opening (nephrostome). A little later a capsule encloses the opening of the head-kidney and the glomerulus—shutting off both from the body-cavity. Originally the waste-products passed directly from the body-cavity, but they are later conveyed from the special capsules to the urinary vesicle behind. As development proceeds the opening between the latter and the gut closes and the fluid has a separate passage posterior to the anus (ureter). In the later stages the lymphatic trabecular tissue in front is traversed by blood-vessels and probably in some by tubules. In the last stages of larval existence mesoblastic cells become aggregated along the dorsal region of the segmental ducts, especially in the fore and hind region, and minute sinuous tubules appear in their midst, which pass down and open into the segmental ducts. In such Teleosteans as the Wolf-fish, in which the later stages of development are well shown, the segmental tubes are absent at first in front, but develop largely when the ducts reach the middle line beneath the aorta, and the pigment having also greatly increased, the structure of the organs thus gradually assumes the adult character.

Generative organs.

As soon as the segmental organs have reached their final position on each side of the dorsal aorta, a strand of cells of the inner fold of mesoblast (splanchnopleure) passes below them. They form the generative epithelium though at first not a genital ridge. On the genital ridge which afterwards appears on either side of the mesentery, a groove develops, according to Jungersen, which subsequently closes to form a canal. In others (Physostomata), the lower edge of the genital ridge coalesces with another ridge projecting from the peritoneum—to the outer side.

Organs of the Hypoblast or inner layer.

Notochord or central axis.

In the earliest section of the trunk no trace of the notochord is visible, a single layer of hypoblast limiting the neurochord below with the plates of the mesoblast above at the sides.

About the time when the lip of the blastopore has reached the equator, a median mass of rounded cells is observed between the neurochord upon which they press and the thin median stratum of hypoblast below—in the middle region of the trunk; it gradually extends forward, ending above the cardiac rudiment on the second day after the blastopore closes.

In the early condition of the notochord the cells forming it are more numerous; thus from six to eight cells extend across the diameter of the chord, due to irregular vertical septa (vacuolation), after the breaking down of cells. Later they form a meshwork, the outermost portions of which constitute a limiting membrane with occasional nuclei. Intruding mesoblast limits the chord below and later still surrounds it with a very thin layer. This is the simple condition of the parts about the 20th day after hatching—the sheath proper being very thin, and the mesoblastic sheath (perichordal) but little increased in thickness. From the latter the future vertebræ are formed, and an external limiting layer can be made out. This structure (external elastic membrane) gives origin to the arches, the upper (neural) preceding the lower (hæmal) in development.

In some forms (e.g. in the snake) cartilage develops precociously in the vertebral column, but in many cases the arches and outer laminæ of the vertebral bodies are not preceded by preformed cartilage but by ossific matter of a clear, homogeneous, and brittle nature. Indeed in more advanced stages a spicular sheath has been found in the connective tissue outside the external limiting membrane.

Branchial system.

In the early embryo the hypoblast forms the roof of the sub-germinal cavity, which has inferiorly the periblast enveloping the yolk. Behind and below the ears a fold grows up on each side of the middle line, meeting with the epiblast on each side of the ears. The lower edges of the lateral folds approach each other in the mid-line, fuse and close in the branchial region of the gut (Wilson). The same takes place with the trunk behind, but Cunningham denies this. Behind and below the ears a large oval area is apparently pushed in, resulting in the perforation of the epiblast on each side.

The formation of the primitive operculum is not readily understood, for the œsophageal lumen is not yet formed. The opercular flap is a much later outgrowth from the tympanic region—which grows backwards over the gill-slits. Below the hind-brain and ears the hypoblast shows a great increase of cells, and beneath them mesoblastic cells make their way, bounded below by periblast, and these become columnar, forming paired rod-like masses.

Some days before emerging from the egg three branchial bars are usually visible, a long thread-like lacunar vessel is found along the posterior margin of each bar, and later a septum forms—constituting an upper arterial and a lower venous trunk.

Five transverse bands, sometimes indications of six, extend across the floor and under the flattened œsophagus, forming a series of mesoblastic cross ridges, and between these the hypoblast is pushed in as septa. The hypoblastic diverticula indicate the future position of the gill-openings, while the mesoblastic margin forms the gill-arches and branchial skeleton. The fifth branchial arch remains rudimentary in the forms dealt with here. In front of the four branchial arches are the stout bars of the hyoid arch, and again in front of these is the mandibular arch with cartilage-cells which are readily distinguished by their height and stoutness. The elements connected with the suspensory apparatus of the lower jaw and the skeleton of the jaws gradually develop. In the young cod three weeks after hatching the branchial system is wholly converted into cartilage. In general the arches have a mesoblastic core and a hypoblastic epithelial covering.

Skull.

At first the brain is covered by a thin epiblastic layer composed of the flattened corneous stratum, and the thick sensory remnant beneath. A sub-epidermal enlargement often occurs beneath this in larvæ in confinement, giving a peculiar outline to the animal. Then the mesoblast is aggregated between the eye and the neurochord, and, passing upward as a thin membrane, invests the brain. Ultimately the three brain-membranes are developed from it, and pigment is also formed on its inner surface. At the time of hatching the base of the brain is strengthened by two masses (parachordals), and in front of these are two cylinders (trabeculæ), which unite posteriorly. Within a week or 10 days after hatching these are converted into cartilage-cells. About the middle of the third week various other cartilages of the skull are formed, e.g. the optic and auditory, but the translucent opercular plates on the surface of the more exposed skeletogenous elements of the face occur later (post-larval stage). While cartilage thus early develops in the skull, that of the axial skeleton is later.

Alimentary canal.

In its earliest condition the alimentary tract consists merely of a thickened layer of hypoblast, intervening between the neurochord above and the periblastic covering of the yolk below. When little more than one-third of the yolk is covered by the blastoderm the hypoblastic cells assume a columnar character, arching over a lumen—beneath which is a floor of periblast. This is the first indication of a gut—the continuity of which with the neurenteric canal and medullary groove has been described. From the arched roof the notochord is differentiated. The lumen extends only a short distance forward, and is lost in hypoblastic cells which reach as far as the cardiac region, where they spread out and form a delicate limiting membrane below the head. The ventral wall of the canal is formed of hypoblastic cells pushed in from the side, or budded off from the nucleated periblast below, probably both[1]. The mid-gut soon, when the invagination of the lenses becomes complete, forms a massive cylinder, and the oral tract a wide sheet of hypoblast. By the time the ear-capsules have thinned out and the otoliths have been developed, a fine fissure traverses the pharynx, and the lumen continues to the blind end of the canal. The cells become cubical and of many layers, and the inner lining has a granular or mucoid appearance. The inner mesoblastic sheet (splanchnopleure) e.g. gives a coating to the canal—forming the muscles and connective tissue, while externally it gives rise to the epithelial peritoneal layer. The œsophageal tract at least appears to be covered with cilia.

At first straight and smooth—the walls of the canal in the later stages become folded and wrinkled—especially posteriorly. Indeed, about 10 days or a fortnight after hatching some forms show a capacious though flattened oral chamber and œsophagus, the latter giving origin to the duct of the swim-bladder. The enlarged stomach follows, the liver lying beneath, with the dense pyloric section posteriorly—the pyloric cæca subsequently springing from it as evaginations, as observed in young cod $\frac{1}{4}$ to $1\frac{1}{2}$ inch in length. From this position also passes the bile-duct. The intestinal walls are likewise dense, and rapidly develop rugæ and a glandular character. Posteriorly the rectal region is marked by a cincture or valve, followed by an enlargement; it then bends downward and narrows to form the small vent—opening upon the muscular papilla.

Mouth.

An involution of the outer layer (epiblast) to form the mouth does not occur in these forms. The oral cavity is capacious and the branchial framework supporting its floor and sides well advanced when a fissure from the chamber bursts through in front. The jaw-cartilages grow rapidly forward, and the mouth, at first ventral and shark-like, opens from above—from the rapid forward growth of the lower jaw.

[1] Cunningham says periblast only. *Q. J. Mic. Sc.*, vol. 26, 1885.

Vent.

In the same way the posterior opening of the gut is not produced by an inpushing of the outer layer (epiblast), but is formed five or six days after hatching by the extension of the internal lumen. At first the aperture is above the ventral margin of the fin, but later the membrane is absorbed, and the condition is almost that of the adult.

Liver.

Soon after the ear-chambers (otocysts) are formed the ventral wall of the mid-gut shows an enlargement anteriorly, and from this the liver arises as a solid proliferation. Into the early organ a delicate canal passes from the fissure of the gut—the common bile-duct. By-and-by the liver becomes bifid—a right and a left lobe being distinguishable—and in the midst a spacious gall-bladder develops. The importance of the liver in the larval fish is shown by its rapid growth into the yolk-sac of the gunnel, and Wilson is of opinion that it is the medium for the absorption of the yolk and periblast.

Swim-bladder.

From the dorsal wall of the alimentary tract the swim-bladder is given off as a very thick-walled diverticulum which presses upwards against the notochord, and remains for some time connected by a fine canal with the gut. Before the embryonic period ends, however, the duct atrophies in the forms under consideration.

In recent years considerable attention has been devoted to the artificial hatching of sea-fishes, especially since their life-histories have been more accurately known. In the *Trawling Report* of 1884 one of us suggested that efforts might be made in our country to augment the "soles, turbot, brill, and other flat fishes," and perhaps also "the cod and other round fishes." "Such an experiment, scientifically carried out, would give a valuable basis for future legislation, tend to increase our knowledge of the food-fishes in a remarkable degree, and would be worthy of the interests which this country has in the department of sea-fisheries[1]." In a later publication[2], when dealing with the same subject, it was distinctly stated that, "It has yet to be proved that the artificial hatching of sea-fishes, even on a large scale, will be beneficial to the fisheries generally; yet the importance of the issue demands that a thorough trial be made." In view of the latter opinion, and when opportunity offered, cordial support was given to the experiment begun by the Fishery Board (previous to 1892) at Dunbar. Until, indeed, the experiment is performed on a scale sufficiently large to give reliable results, criticism on the general question is unnecessary, though in some cases it may be valuable in the suggestion of methods.

[1] *W. C. M. Trawling Report*, 1884–85, p. 379.

[2] *Ibid. A Brief Sketch of the Scottish Fisheries*, 1892, p. 15.

CHAPTER VI.

THE RATE OF GROWTH OF FOOD-FISHES.

THE importance of this subject from an economic point of view would be difficult to exaggerate, and at the same time it is remarkable how very little is definitely known in connection with it.

It has already been pointed out in the Introduction that the various changes undergone by a fish in its transition from the egg to the adult condition fall under two heads,—firstly, quantitative changes, which involve increase in bulk, and secondly, qualitative changes, or those which are concerned with the differentiation of organs.

It is well to understand clearly that these two series of changes have not necessarily any direct connection, although the quantitative changes of growth appear to precede to a great extent those of development or differentiation.

These quantitative changes which cause the phenomena of growth are held by most zoologists to be either the direct effect of, or intimately connected with, cell-division. Thus if cell-division takes place at a more rapid rate than the loss of cellular tissue to which the organism is constantly subjected, the result is an increase in the number of cells and of general bulk, or, in other words, growth, and so far as is known there is no inherent reason why this growth should not proceed throughout the life of the organism. We do not mean by this that there is no limit whatever to the size attainable by any given species; thus, to quote Weismann, "although many fishes, reptiles and lower animals are said to grow during the whole of their life, we do not mean by this that they possess the power of unlimited growth any more than that of unlimited life. There is everywhere a maximum size which, as far as our experience goes, is never surpassed. The mosquito never reaches the size of an elephant, nor the elephant that of a whale."

Limit of Growth. The problem of the growth of fishes is thus very different in many ways from that of the growth of quadrupeds and birds. As one would expect, from theoretical considerations, the fish as an organism shows itself to be more directly susceptible to the influence of its environment. Thus, as mentioned below, the period of incubation can be altered at will between very wide limits by simply varying the temperature, whereas one would hardly expect to alter the period of mammalian gestation, or even of avian incubation, except within extremely narrow limits. Other instances could easily be given to show that the direct effect of the environment upon the piscine organism is much greater than that upon land organisms. Without considering the effect of environment it is probable that the life-cycle of the individual fish also differs in very important respects from that of the higher animals.

'In the mammalia there is a definite duration of growth in bulk and of life quite apart from the environment, and either period can only be altered by continued action of the environmental factors through many generations. There are some experiments which point to the conclusion that the duration of life of the individual fish is only limited in the widest sense (with immunity from environment), but leaving this out of the question there is no proof of the hypothesis that the individual fish ceases to grow at any period of its life; on the contrary, there are considerations which point to the other view, i.e., that a fish continues to grow throughout its life.

'Thus, if a mammalian or avian species be subjected to the destroying agency of man, there follows a *diminution in numbers;* whereas, if a fish be subjected to like conditions a *reduction in the size of the individuals* is the immediate result. These facts can be explained as follows:—In the former case very little, if any, growth in size takes place after the attainment of sexual maturity, whereas, in the latter case, growth continues indefinitely after that event[1].

We may take an example to make this clear. Let us suppose that a certain fish of species A first comes to sexual maturity at a size of 6 inches, and that it grows 1 inch a year, and continues to reproduce its kind annually up to a length of 20 inches. In this case there is an active reproductive period of 14 years. It is a well-known physiological fact that the period of reproduction is not constant in intensity from its inception to its end, but both in quantity of eggs laid and vigour of offspring it varies, attaining a maximum in the middle and minima at each end. In this way the fish although attaining maturity and producing sexual products at a length of 6 inches will then only produce smaller and weaker offspring, whereas by the time of reaching, let us assume, some 19 inches, offspring of greatest vigour will be the result. In a state of nature a balance is struck and both kinds are found living together, or rather, to be more accurate, every gradation, from those maturing from the first time at 6 inches and those maturing at 10 inches. Now let us consider the effect of overfishing. Assume that fishing has been carried to such an extreme that an inappreciable quantity of fishes reach the length of 10 inches, so that only those are left which commenced breeding at 6 inches and somewhat upwards, and their offspring will have the same tendency to commence breeding at the earlier age and shorter size. The first effect will therefore be that of reducing the average size of the fish.

It is a well-known fact that a far greater number of fry are annually produced than will ever attain sexual maturity, and the numbers surviving in any given district till sexual maturity will bear a constant relation to the amount of nutriment supplied by that area. Returning to our example let us suppose that in a given district at a given time there are of species A (1) 50,000,000 adults past their maximum reproductive capacity and of 12 to 24 inches in length, (2) 100,000,000

[1] A. T. M. 'Rate of Growth of Marine Food-Fishes.' 13*th Ann. S.F.B. Report*, p. 289.

at a length of 8 to 12 inches at the maximum age and length for reproductive purposes and (3) 120,000,000 at a length of 6 to 8 inches which have reached the inceptive stages of reproduction, and (4) 300,000,000 immature individuals. For the present purpose we may neglect the (1) and (4) and consider (2) and (3).

The effect of over-fishing is to remove the second series, for apart from other reasons the members of (2) have been subjected to the risks of being caught at stage (3) before attaining to stage (2).

The removal of (2) and with it (1) means that, the supporting powers of the district remaining the same, a much greater quantity of (3) and their offspring included in (4) will be able to find subsistence and will survive. Hence the second effect of over-fishing a district will be that of *multiplying the numbers.*

The results at which we have arrived here are found in nature. One of the most obvious effects of over-fishing a district is that there results a great number of small-sized individuals of the particular species affected. Looked at from a general aspect we may express this result thus: The species is subjected to risks of extinction and the counteracting effect is a reactive production of a greater number of smaller individuals, so that extinction may be prevented by multiplying the chances of a sufficient number reaching sexual maturity. The want of this ready re-activity to changed surroundings in mammals helps to render the whales and seals liable to extinction at the hands of man.

In the case of birds and quadrupeds these laws apply, as already stated, only to the extremely limited extent to which the attainment of sexual maturity and the cessation of growth do not quite correspond in point of time. Hence protective reduction in size of a bird or mammal can only take place at an extremely slow rate.

The amount of growth of a fish *per annum* may be expressed as a certain proportion of the whole, and must form an ever-decreasing geometrical series, so that the total amount of growth is only limited in the same sense as $1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8}$, etc., is limited in a finite series to less than 2. A study of the average sizes of fishes shows that the annual increase is practically distinctly appreciable. There is no reason, therefore, to believe that there is any definite limit to the size of a fish, as used in the sense in which we speak of a definite size attained by mammals and birds, beyond which growth in bulk does not proceed.

Exceptions to this rule have been put forward from time to time; for example, some observers hold that the herring forms one of these, so that after attaining a definite size it entirely ceases to grow. It seems, however, that these statements, though handed on from one authority to another, do not rest upon sufficient basis of fact.

We may next enquire consecutively into the various factors of environment which are known to affect the rate of growth of fishes.

Nutrition. The direct effect of nutrition upon growth is well known, even in the case of the higher animals, so that the result is probably intensified in the case of fishes. This factor obviously cannot come into force till the post-larval stage is reached, for before this, the larva is supplied with a copious quantity of yolk-material, which though doubtless varying in slight degree may be reckoned as constant for all practical consequences.

Dr Meyer in 1878 made experiments with young herrings, and found that those reared artificially grew at a slower rate than those living under natural conditions, but that later they, so to speak, made up the leeway. This is shown as follows:—

	Length in millimetres attained by fish under	
Age from impregnation.	Artificial conditions.	Natural conditions.
One month	10—11	17—18
Two months	17—19	24—36
Three months	30—35	45—50
Four months	48—54	55—61
Five months	65—70	65—72

From this table it can be seen that the two months' herring brought up in captivity are some of them less than half the size of some of the same age reared under natural conditions, but that at 5 months the average sizes are closely similar. Dr Meyer was inclined to ascribe the small size of the former to the insufficient or unsuitable food.

Detailed experiments have yet to be made with regard to the direct effect of varying the supply of food upon the growth of fishes of a more advanced age than these herrings.

Temperature. One of the commonest observations in respect to the development of fishes is the great variation in the length of the period of incubation according to the temperature of the surrounding medium; indeed it is now usual for naturalists in quoting the duration of incubation, in any given instance, to mention the temperature of the water in which the eggs were hatched.

Dr Meyer, in the same series of observations as above referred to, experimented with the eggs of the herring, and came to some important conclusions. He found that at a temperature of 51°8 F. to 53°6 F. they hatched in 10 to 11 days, but at a temperature of 35°6 F. the embryos emerged on the 29th to 33rd day, and even later. Again at 32° F. the hatching period was postponed till the 47th day, and at 30°56 F. normal development was no longer possible. At this low temperature the yolk became opaque and burst the egg-capsule, thus destroying the embryo. He also found that the influence of cold in retarding growth is more marked upon the later stages than upon the earlier[1].

It might at first be supposed that we have here a phenomenon of retardation of development or differentiation and not of growth, but it must be remembered that in Vertebrate embryos all the earliest stages are almost entirely taken up with processes of growth or cell-division, and that differentiation of organs only takes place later, so that it is not a great assumption to suppose that we have to deal mainly with the retardation of growth.

Recently Mr Harald Dannevig[2] has attempted with some success to determine in an exact manner the connection

[1] *Vide* also W. C. M. *Nature*, Vol. 34.

[2] Superintendent of the Hatchery at Dunbar.

between the duration of the incubatory period and the temperature. Thus by hatching eggs of some of the commoner species at successive constant temperatures and comparing the results, he has been enabled to make curves dependent on geometrical principles, which show the exact length of the period of incubation at any given temperature. The subjoined table is a reprint from his work[1]. He was led, from his observations, to the following conclusions:—

'1. That the period of incubation is various under the same circumstances for different species.

'2. That this difference is in relation to the size of the eggs in this way, that the large eggs take a longer time than the smaller ones.

'3. That the time of incubation for the same species varies according to the temperature.

'4. That this variation for each degree is comparatively larger in a low temperature than in a high.

'5. That development of fish-eggs takes place also at temperatures below zero (Centigrade), when the specific gravity of the water is sufficiently high to prevent it from freezing.'

Dannevig obtained almost the same results with the eggs of the cod and those of the haddock, but it is well to remember that although the average size of the former is slightly smaller than that of the latter yet the two overlap each other considerably. Thus Mr Williamson[2] recently found that out of a considerable number of examples, the smallest cod's egg was 1·35 mm. in diameter and the smallest haddock's egg was 1·38 mm., whilst the largest haddock's was 1·458 mm. and the largest cod's was 1·467 mm. in diameter. The mean

[1]

Fahrenheit temp.	28°·4	30°·2	32°	33°·8	35°·6	37°·4	39°·2	41°	42°·8	46°·4	50°	53°·6	57°·2	
Centigrade temp.	−2°	−1°	0°	1°	2°	3°	4°	5°	6°	8°	10°	12°	14°	
Cod		42				23	20½	17½	15½	12¾	10½	9⅔	8½	Time of incubation in days.
Whiting							15⅓	13½	10¼	8		6½	5¾	
Haddock		42				23	20½	17¾	15½	13	10¾	9⅔	8¾	
Plaice									18¼	14⅓	12	10½		
Flounder									6½	5½	4½	3⅔		

[2] 13th Ann. S.F.B. Report.

size for cod's eggs was 1·386 mm. and that for haddock's was 1·458 mm. These figures show that the two species have eggs so near in average bulk that the difference is probably inappreciable by the apparatus used by Dannevig.

This third conclusion is suggestive. Would it not be possible, with exact physical apparatus to show that at a constant temperature the time of incubation is inversely as the mass, or inversely as the relationship of the bulk to superficial area, or in some way to reduce the *specific* variation in time of incubation to a function of the mere bulk contained within each egg?

Passing to the further effect of temperature-variations upon the growth of the older fishes, there are a number of observations which tend to show that fishes as a rule grow very little during the coldest months of the year.

Pathological. Fishes appear to be very susceptible—as regards their growth—to slight injuries. Small abrasions of the surface of the body seem to have a marked retarding effect upon the growth of the individual. The importance of this will be seen later.

Lastly, we have to deal with what we may term the 'individual tendency.' It is an accepted axiom that individuals vary not only in size but in other respects, and there is no reason to hold that the rate of growth forms an exception to this statement. In the same brood marked differences occur in the size both of the eggs and embryos and there is reason to believe that, *cæteris paribus*, these differences become accentuated as time goes on.

These factors, briefly touched upon, form such a formidable array of tendencies, all active under natural conditions and all working to the same end, namely, diversity of growth, that they might well appear to make the rate of growth of fishes an insoluble problem, but we do not think matters will be so hopeless as this if carefully considered.

Under natural conditions, all the fishes of a species in a given limited area have the same habits and all are subjected to approximately the same conditions of temperature, the pathological element may be eliminated by selections of specimens, and the 'individual tendency' has a correcting factor in the action of natural selection. Thus the mean average size of the species at every stage has been determined under natural selection, as that which has the greatest immunity from destructive tendencies of every sort, and greatest chances of surviving; and the same destructive tendencies still act upon every generation to weed out the maxima and the minima to the preservation of the mean, so that after the early stages the largest or smallest are continually removed, the mean only surviving. This fact is important, for it follows from the same, that if one takes a number of fish-eggs or young larvæ, *already varying in slight degree* as regards size, and places them in tanks in artificial conditions—such as easy access to food, and immunity from actual foes; then, all the slight variations in size tend to be emphasised, and in course of time fishes of very various sizes will result[1].

This does not come under the head of a theoretical hypothesis except to those, a few of whom may yet be found, who will not acknowledge the principles of natural selection, the struggle for existence, and the survival of the fittest.

In natural conditions, especially in gregarious fishes, the environmental factors of temperature, nutrition, &c., must be very closely similar, if not identical, for all the individuals of one brood, so that, taking this into account, and also what has been stated about the variation, there are good grounds for supposing that the rate of growth is closely similar for each individual, and that a *mean average* length for any given species at a given age is a fixed and determinable quantity. The greater the difference in environment the greater the difference in the mean average, till 'forms' may become marked.

Thus, in estimating the rate of growth, the great effect of marks or abrasions upon the fish precludes the employment of this method of procedure, although apart from this drawback it enables us to study the growth-rate of individuals under their actual conditions.

The method of rearing young fish in confinement and measuring them periodically must be condemned once for all

[1] A. T. M., *loc. cit.*

as absolutely useless; for, although the temperature may be registered, the conditions of nutrition and the exclusion of the check caused by natural selection upon 'individual tendencies' make all results obtained in this way abnormal and useless.

This method has been resorted to by Mr Cunningham at Plymouth and by some other workers. Although we have under the heading of each species quoted some of his observations by this method, yet from what we have remarked above, it will be manifest that there are strong objections (which cannot be lightly dismissed as being 'theoretical') to conclusions deduced from such experiments.

This being the case the growth of fishes under natural conditions must be studied in another way.

If a great number of fishes be caught and measured and the date of capture registered, and again, if the spawning-period of the species be known, then the age of each fish may be estimated with a fair degree of accuracy. A number, the more the better, may be caught and measured at one date and the *mean* size determined; we may then assume that the individuals of mean size at any date correspond in age with the mean spawning period, or the period in the middle of the spawning-time—at which there are always the greatest number of eggs laid. In doing this we assume that the greater part of the diversity in size of one 'haul' of fishes, if they are within a year of each other in age, is due to the extended spawning-period; in fact, is due to a greater or lesser age. A great number of facts and observations tend to bear out this hypothesis. The method is probably capable of great accuracy, provided a sufficient number of specimens are caught and measured and the true *mean* for the district thereby determined, but approximate results may be obtained from even a few specimens, by gauging the age of each individual, within the limits allowed by the spawning-period, as being that which best corresponds with that of a different age. If the age of each fish be expressed by a point upon a curve then each is so estimated as to make the curve as regular as possible. Here we assume that the individual fishes are derived from eggs spawned at different times. The method is capable of a fair degree of accuracy but one or two extreme cases may considerably upset the results.

A comparison of the curves derived by this method with the table of maxima and minima of sexual maturity given in this chapter shows that the majority of the food-fishes attain sexual maturity for the first time during their third year, and in the case of the males it is very likely that most come to maturity during their second year. As in other remarks concerning fishes in this department we must be understood to refer only to the average, and indeed it is likely that the *average* attainment of maturity may be as late as the third and fourth years for males and females respectively.

Further we may notice that the larger species of fishes appear to differ from the smaller in their size mainly on account of a greater rate of growth from the outset, by which is meant, from the hatching epoch, although the size of the egg and newly hatched larva only corresponds in a very rough way to that of the adult. Thus the ling shows a more rapid rate of growth during the whole period of maturity than the gurnard or smaller species, and the same applies to the plaice amongst flat fishes compared to the dab and others.

We have, up till now, left out of consideration all points in connection with differentiation of organs. This development, proceeding contemporaneously with growth, reaches a culminating point in the maturation of the sexual organs. These are the last organs of the body to become functional, and a fish which has reached this stage may be known as 'mature' or 'sexually mature,' while one which has not yet become sexually functional is 'immature.' Some observers have attempted to apply these terms as if they were synonymous with 'fully-grown,' but from what has been said above, the latter term is meaningless and even misleading as applied, at any rate, to the vast majority of fishes. If we wish to speak of young and adult fishes we can only do so by selecting an anatomical or physiological feature as a line of demarcation between the two, and the feature which is eminently suitable for this purpose is that of functional sexuality. The terms 'immature,' 'mature,' 'young' and 'adult' can not be scientifically defined in any other way. Dr Fulton insisted upon the same interpretation of the terms 'immature' and 'mature,' in 1889[1], and determined the average size limit of immature individuals in the case of several of the commoner species.

His work led him to conclude that the following sizes represent the lowest length, without reference to sex, at which maturity is nearly reached in the following species:

Plaice	12 inches	Turbot	18 inches
Lemon-dab	8 "	Brill	16 "
Dab	6 "	Sail-fluke	9 "
Flounder	7 "	Haddock	10 "
Witch-sole	12 "	Cod	20 "
Long-rough dab	6 "	Whiting	8 "
Little sole	3½ "	Gurnard	8 "

Cat-fish 20 (?) inches.

The practical application of our knowledge of growth-rates depends largely upon the determination for each species of the average size and age at which sexual maturity is reached.

A large number of fishes may be caught and measured and their sexual organs examined, and we may thus determine roughly a mean minimum size for the attainment of maturity; and this has been done in a great number of cases. The results of examination of a number of fishes caught by the 'Garland' show the following maximum and minimum sizes which were sexually mature[2]. Whilst those below the minima were not sexually mature, it does not follow that individuals above the maxima no longer spawn, in fact, a cod of 46 inches is, on the same Table, recorded as in the 'spent' condition.

	Male.	*Female.*
	Inches.	Inches.
Cod	23—37	36 (only one example).
Haddock	12—16	14—24
Whiting	9—15	9—18½
Bib	8—8	7½—10

[1] T. W. Fulton, *7th Scot. Fish. Board Report*, p. 161.
[2] T. W. Fulton, *10th Scot. Fish. Board Report*, p. 239 a.

	Male. Inches.	*Female.* Inches.
Gurnard	11—16	8½—18
Long-rough dab	5—8	5—16½
Plaice	13—22	20—28
Lemon-dab	8½—16	11—19
Dab	6—12	5½—17
Flounder	6—14	7—17½

By this method one important fact has been brought to light, namely, the difference in size between the sexes. It appears to be the rule that the attainment of maturity takes place at a different size in the two sexes, the male pretty generally being the smaller among Teleosteans. Occasionally, as in the long-rough dab and the salmon, this is very marked. Here again we have the same two alternatives by which to explain the facts. Does the male grow more slowly than the female, both maturing at the same time? or does the male mature at an earlier age, the rate of growth for the two sexes being the same? In other words, which varies—the rate of growth, or the period of development?

We have data which distinctly point to a variation in the duration of the development, the male sexual organs maturing at an earlier date than the female. This is undeniably the case in *Myxine*, and also in the salmon. Thus we may assume that the rate of growth in the two sexes is closely similar. Both sexes are placed under the same environmental conditions, and hence a different rate of growth would be at least improbable, whereas the more *rapid* maturation of the male elements may be traced to a deep-seated origin which may be best explained by the following remarks by one of us[1].

"There are numerous facts in the ontogeny and structure of the Vertebrata which point to a hermaphrodite chordate ancestor.

"Amongst these we may cite Nansen's observation of the protandric hermaphrodite condition of *Myxine*[2] and the

[1] A. T. M. 'Hermaphroditism in the Cod,' 13*th Scot. Fish. Board Report*, p. 298.

[2] *Aarsber. Bergens Mus.* 1887, op. vii.

important fact that amongst Teleosteans, as a rule, the males are considerably smaller than the females, and there is in some cases (salmon, etc.) certain proof, and in others a great probability, that the males are mature at a much earlier date than the females. Above the fishes also, many of the Amniota show a tendency for an earlier maturation of the male products. The bearing of this may be seen as follows:—We may suppose the primitive hermaphrodite chordate ancestor to have a continual rhythmical and perhaps seasonal predominance of one sex more or less directly dependent upon the environment (cf. Yung's[1] observations upon Tadpoles). The tendency for a seasonal repetition of the same environment would then have the effect of causing a perfectly rhythmic sexual cycle, from male to female, in each individual. This would be a case of polycyclic hermaphroditism.

"This condition appears to be exemplified in the abnormally hermaphrodite Teleosteans. The lengthening of the cycles would result in a monocyclic hermaphrodite condition, as still persistent in *Myxine*, and lastly, the reduction of the stage at the commencement of the cycle to vanishing point in some individuals (females), and hypertrophy of the former half in others (males), would cause a hemi-cyclic diœcious species, as exemplified by all other vertebrata. If we may regard this as, in a general way, the line upon which the diœcious condition has been evolved phylogenetically in the chordata, we have an explanation of the facts of the earlier maturation of the males."

If the maturation of the sexual organs takes place in a certain district at a smaller size than is the case with the average, then a "race" or variety of smaller fishes ensues. Thus the plaice in the south of England, as far as statistics go, appear to be smaller on an average at the attainment of maturity than those, e.g., on the east coast of Scotland; and Petersen deduces facts to show that a smaller 'form' is present in the Baltic than in other Danish waters; while in Iceland and certain other regions a 'giant race' predominates. If we assume that in all these 'forms' the sexual organs mature at

[1] *Arch. Zool. Expr.*, vii. *Arch. Sci. Phys.*, Nat. xiv.

the same lapse of time from the hatching date, then the different rate of growth, due to the different environment, would account for the smaller size.

The other alternative is to assume an approximately constant rate of growth in each case, and an earlier (in time) maturation of the sexual organs.

Further investigation alone can show whether one has to deal with a case of a *hastening of sexual development* (pædogenesis) or a *retardation of growth.* Petersen is inclined to think that the period of attainment of maturity (roughly three years in the Danish waters) corresponds with that of our east coast 'form' of plaice, which rather indicates the latter.

We may perhaps appeal to a similar series of phenomena to account for these 'races' or 'forms' as in the case of the effects of over-fishing (see above). If in a given district the increase of natural enemies to the plaice is so great that their influence may have the same injurious effect as that of over-fishing by man, then a small form would result, and this would possibly be assisted in warmer regions by earlier maturity, whereas in districts where the species is comparatively unmolested, and especially when in the colder climes, with, for this reason, a retarded sexuality, a larger race or 'form' would be evolved.

This phenomenon of 'forms' practically resolves itself into a special case of the general law stated in the early part of this chapter, namely, that the mean average size of the species *at every stage* has been determined under natural selection, and is obviously mutable under changed conditions.

It is convenient to express the facts of growth-rate by growth-curves. These curves are intended to express the normal rate of increase in length of the species under natural conditions, and we should add, in the particular environment in which the specimens were caught. It is preferable to gauge the size of a fish by its length because this dimension is most readily determined, and in consequence all 'prohibitive' legislation must adopt a standard of length. From a scientific point of view the method, as expressing comparative increase in bulk, is inaccurate, for in comparing the growth-curves we must assume that the length is in all cases an equivalent proportion of the whole bulk, and this is not so. The curves, for instance, of the gadoids may be compared amongst themselves with a fair degree of accuracy, but a glance at the shape of a pleuronectid will at once remind the reader that the length is a less predominant factor of the total bulk than is the case with a gadoid.

It is well also to bear in mind that the length is not a constant factor in the bulk of a single fish throughout its life; and it bears a greater proportion to the other dimensions as a rule, in the younger stages, so that the curves cannot in any way be said to represent accurately the increase in bulk or total growth of the species in question.

Any rhythmical disturbing factor in the growth under natural conditions should appear in these growth-curves as a constantly repeated deflection in the curve, so that the seasonal variation in temperature should, if the curves were quite accurate, cause a recurrent series of secondary curves.

The method of investigating rates of growth, as described and advocated here, depends, as already stated, upon a knowledge of the spawning-period, and the inverse to this holds. Thus, given a sufficient number of specimens of a certain species and their date of capture, the curves of maximum and minimum size at every stage may be defined, and these, produced back to the base line, will give the duration of the spawning-period. This method has been pursued recently for the herring[1] and the sand-eel[2] and shows that both these forms have two spawning-periods in a year, besides indicating other important facts, such as the difference in size and rate of growth of the spring and autumn 'races' of herring, and the habitat of the young fishes at each stage, as mentioned under the sections devoted to the herring and the sand-eel respectively. Table A will give a good idea of this graphic method of representing the rate of growth and life-history of the herring; the gradual progression of the young forms as they

[1] A. T. M. 'Rate of growth of the Herring.' *14th Scot. Fish. Board Report.*

[2] A. T. M. 'Life-history and rate of growth of the Lesser Sand-eel. *Annals and Magazine of Natural History*, Sept. 1895.

grow, through the mid-water and surface and thence to the shore, is indicated by special markings at each stage.

It may be noticed that the close approximation to the same parallel of the limiting curves is an additional justification of the view that the greater part of the disparity in size of young fishes at any date is due to a disparity in age, which is itself made possible by the prolonged spawning-period.

Further remarks upon this table will be found in the part dealing with the herring.

It is patent to all that, notwithstanding what has been done in this branch of ichthyology, the results are at present very meagre, and although the experiments upon fish-eggs may lead us in the right direction for elucidating the laws which govern the growth of fishes and may enable us eventually to reduce them to concrete terms, yet this end is at present distant. Every step in advance has however its peculiar interest from a general point of view, for the fishes, with their simpler organisation and their less fixed and definite predetermining influences, lend themselves the more readily to experimental investigation, and form a vantage point from which to make a flank attack upon the great problems of growth and reproduction—as exemplified in their greatest complexity by the higher Vertebrates, including man himself.

PART II.

LIFE-HISTORIES OF THE SPECIES.

CLASS PISCES (FISHES).

Aquatic vertebrates breathing by gills. Heart, as a rule, of two chambers; blood cold. Two pairs of limbs in the form of paired fins supported by fin-rays are usually present, and are not divided externally into arm, fore-arm and hand, or thigh, leg and foot. They are the only animals possessing median fins supported by fin-rays. A row of sense-organs along each side of the body. Skin generally covered with scales. No amnion and no allantois.

SUB-CLASS I. TELEOSTEI (BONY FISHES).

Skeleton bony, with well-developed skull. Tail externally symmetrical (though it may not be so structurally). Brain with large optic lobes; optic nerves simply cross; olfactory organ double. Gills free, in one chamber, and with one aperture of exit behind the gill-cover. Heart with a non-contractile bulb at the origin of the aorta. No spiral valve in the intestine, which opens independently of the urinary and genital apertures. Air-bladder usually present. Eggs numerous, generally small, almost always fertilized in the water.

ORDER I.

Acanthopteri.

Fishes generally having ctenoid scales. Ventral fins thoracic or jugular. Some of the fin-rays spinous, that is, unarticulated. No duct to the air-bladder (physoclistous).

CHAPTER VII.

LIFE-HISTORIES OF THE SPECIES.

The Perch-Family. (Percidæ.)

THE SEA-PERCH. (*Boccus labrax*, L.)

THE eggs of this species have not been procured in a ripe condition, and indeed, on the east coast, the fish rarely comes under notice. On the west coast, however, as at Southport, observations should be comparatively easy. Day considered that they deposited their spawn about the mouths of rivers during the summer months; while Couch states that July and August are the breeding-months in Cornwall. Thompson found the ovaries enlarged about the end of March, and the eggs about the size of millet seeds. Raffaele found the ripe pelagic eggs of the sea-perch in the Mediterranean from January to the beginning of March, and from what has been observed in a large female at St Andrews in May the spawning-period would seem to be late, for the ova were comparatively small[1].

The eggs, which, according to Raffaele, range from 1·155 mm. to 1·2 mm., have the usual pelagic characters, viz. a transparent capsule, homogeneous yolk and an oil-globule with a diameter of 0·333 mm. to 0·366 mm. (Plate I. fig. 2). Occasionally two or three oil-globules may be present, as in the gurnard and other forms. During the development of the egg blackish pigment occurs along the dorsum, and yellowish pigment on the sides. The latter colour also appears under the oil-globule. The abundance of the pigment and the large size of the chromato-

[1] W. C. M. *6th Ann. S.F.B. Report*, 1888, p. 276.

phores, indeed, form a feature of the egg. Hatching occurred in three or four days.

The larva (Plate V, fig. 1) measures on extrusion 2·5 mm. and is thus about the size of the American species (*L. lineatus*). It is distinguished by the presence of the large oil-globule with its yellow pigment at the posterior and inferior border of the ellipsoidal yolk, by the presence of a pre-anal marginal fin of considerable length, for the vent is far back, and by the yellowish pigment of the body and anterior part of the yolk-sac. No pigment is present in the eye. On the 6th day (Plate V, fig. 2) the larva measured 4·7 mm. to 4·8 mm., and the pigment had grouped itself in two massive touches on the body, besides patches on the head, tail and yolk-sac, but instead of the yellowish hue it was now greyish-brown, with black corpuscles along the abdominal roof. Only at the tip of the tail did the pigment pass into the fin-membrane. The yolk soon disappeared, and by the 12th to the 15th day the post-larval sea-perch had the vent about the middle of the body, with a long pre-anal marginal fin, bluish eyes, very large ear-capsules, erect breast-fins and a deep brown pigment-band along the lower border of the muscle-plates from the swim-bladder nearly to the tip of the tail, only a short line of pigment occurring on the opposite border of the muscle-plates in the tail. The head is somewhat large and the mandible massive.

Closely allied young percoids 11 mm. in length were sent from Naples by Mr H. C. Williamson in June.

The Comber or Smooth Serranus. (*Serranus cabrilla*, L.)

This species is common off the Channel Islands and the southern coast, and occasionally is procured in the Moray Frith. All that Day observes with regard to reproduction is that the ripe fishes occurred at the end of summer or in August and September. Raffaele studied the egg at Naples, where he found it in spring and the beginning of summer. The egg (Plate I, fig. 3) is pelagic, as first stated by Hoffman, comparatively small, viz. 0·90 mm., with a small oil-globule measuring 0·15 mm. in diameter. The pigment in the developing embryo is slower in making its appearance than in the sea-bass, but the tints are similar, viz. yellowish and black. On its escape the small larva (Plate V, fig. 3) is characteristic, the large ellipsoidal yolk projecting in front of the depressed snout, while the oil-globule is ventral and median. A pre-anal fin is present. The pigment-corpuscles are few, but pronounced above and below the muscle-plates, and occur toward the posterior third of the tail. By the fourth or fifth day (Plate V, fig. 4) the eyes are pigmented, the yolk has disappeared, the mouth is widely open, the pre-anal marginal fin is long—with a pigment-spot in front of the vent, and some chromatophores have appeared in the marginal fin dorsally and ventrally.

The Red Mullet-Family. Mullidæ.

The Red Mullet. (*Mullus surmuletus*, L.)

To those accustomed to the trammel-net on the shores of Guernsey and the Channel Islands generally, not even the numerous blue sharks and huge spiny lobsters that meet one under these circumstances are more interesting than the bright orange-red mullets that entangle themselves in the meshes. Their striking coloration and the eagerness with which their large lateral scales are torn off by the fishermen to impart to their prizes that reddish tint so popular in the market, impress themselves on one's memory. This fish has pelagic eggs (Plate I, fig. 1) having a diameter of 0·93 mm., a single large oil-globule with a diameter of 0·23 mm., and which in the tanks at Naples, Raffaele tells us, were shed in great quantity in early spring. The egg, further, is characterised by the very evident pores of its capsule, by the large vesicles of its yolk—most distinct at the surface, but which change position during the growth of the embryo, and by the proportionally large oil-globule, under which pigment is developed after fixation. Black pigment only, and that sparingly distributed, appears on the body of the embryo. The eggs hatch in three or four days, and the larva (Plate V, fig. 5) has a remarkable aspect for the yolk projects in front like a prow with the oil-globule at the tip, and the vent is close to its posterior border, while sparsely distributed black stellate pigment occurs along the dorsum and sides. By the second day the prow of yolk has been considerably abbreviated, and a larger space exists between the vent and the receding yolk, while the *f*-shaped curvature which characterised the newly-hatched fish is now scarcely noticeable. The usual extension of the marginal fin forwards to the mid-brain and the appearance of larval sense-organs have also taken place. Between this and the 7th or 8th day the yolk has entirely disappeared (Plate V, fig. 6), and the black pigment has grouped itself chiefly along the ventral border of the muscle-plates with a very little on the side above, in the middle of the body, and a speck above and below the plates about a sixth from the tip of the tail, and also along the abdominal roof. The eyes are richly pigmented and resplendent. In the middle of June, and in July and August, Raffaele also found young fishes (2—3 cm.) with a barbel and silvery aspect, for the roseate colour had not yet appeared.

In the young examples described by Malm[1] the profile of the head is almost like that of the cod, but as it increases in size the interorbital space rises so as to give it the characteristic form of the adult. Cunningham mentions that young examples, 3 inches long, occur in Plymouth Sound in summer. He considers them a year old.

The Bergylt-Family. Scorpænidæ.

The Norway Haddock. (*Sebastes marinus*, L.)

As one of the two British viviparous forms amongst bony fishes this species is of special interest, though few opportunities have been had of examining it, the only specimen in the collection at St Andrews having been obtained from Mr Sim, of Aberdeen. It was brought from the Moray Frith, where it occasionally occurs. It is common off the Norwegian shores.

[1] *Goteborgs och Bohusl. F.*, p. 383, and *Scandin. Fishes*, p. 63.

Ekström and Smitt observe[1] that the male is generally rarer than the female. The eggs are fertilized internally and developed on the walls of the ovaries. Collet considered the number of eggs in a female 550 mm. long (21·5 inches) to be about 148,000. Ryder, however, estimates the number of embryos in each ovary to be about 1000, and thus it is probable that only a portion of the eggs arrives at maturity at the same time[2]. He also believes he had found an abundant covering of flat, fleshy and highly vascular processes which to some extent corresponds to the maternal placenta of vertebrates. Ekström frequently had one of both sexes forwarded to him, and therefore he was inclined to think the fish monogamous. He found the embryos far advanced at the end of May, while Kröyer stated they left their parent in July when they are from 3 to 5 mm. in length, and swam near the surface. In the same month (July) they reach from 9 to 19 mm. in length, and are captured in the surface-nets. They soon, however, seek the lower regions of the water.

In an example procured from the Moray Frith the surface of the ovary was furnished with a vast number of villous processes, smaller and finer than those in the viviparous blenny. They were more or less digitate, lobed processes, which presented numerous small blood-vessels and various minute ova—ranging from ·0762 mm., or under, to about ·2286 mm. The larger forms of these projected from the surface either as sessile or pedicled processes, and their subsequent history is probably closely analogous with that of the viviparous blenny, the numerous long vascular processes, amidst which they were, having formerly carried developing ova from which the embryos had now escaped. The free embryos in the ovarian chamber were all of the same size, viz. 4·9 mm., and generally had the body bent round on the yolk, some of which still remained. The eyes were deeply pigmented, and black chromatophores occurred along the roof of the abdomen, dorsally along the edge of the muscle-plates, and ventrally to a less extent in the caudal region, the pigment of the dorsal line

[1] *Scand. Fishes*, p. 152.

[2] See Ryder, *Bull. U.S. Fish Com.* Vol. VI. (1866), p. 92.

almost coming up to that on the abdomen, while the ventral series is confined to the tip. The specimens were very indifferently preserved, but the marginal fin showed no fin-rays except in the caudal region, the tip of which had well-marked embryonic rays. The pectorals seemed to be little developed. The hyoidean and mandibular cartilages were fairly developed and the mouth open.

So far as could be ascertained from this example there were no signs of a rapid succession of series of eggs, but, on the contrary, a wide interval evidently existed between the free embryos and the largest of the developing eggs, an interval probably extending over an entire season.

The appearances of the villi pointed to their having similar functions to those in the viviparous blenny, viz. to supply amongst other things a nutritive pabulum for the embryos, and this before any special development of the intestinal canal of the embryo could take place.

The larvæ of *Scorpæna* abound at Naples in June, but Mr Williamson did not make out the species.

The Sea-Scorpion-Family. Cottidæ.

The Short-spined Sea-Scorpion. (*Cottus scorpius*, L.)

The short-spined sea-scorpion was one of the fishes very early examined in regard to spawning during the trawling work of 1884 and the following year. Comparatively little was known previously in regard to it. Thus Day, in his *British Fishes*[1], states that, 'In Greenland it has been observed to deposit its eggs on the seaweed in December and January. Its eggs are very small, and in this country are extruded during the spring in the sand or pools in the rocks. The male is said to make a nest of seaweeds and pebbles for the reception of the spawn; while he is believed to watch over, as well as protect, the young when hatched.' On the other hand, Prof. Alex. Agassiz records the ova of certain American Cotti

[1] Page 186.

as pelagic, a feature very different from those of our country, and probably requiring corroboration. Whether he had the condition of *Scorpæna* with its ovoid floating mass of mucus and eggs in view is unknown. On the east coast, as at St Andrews, the eggs of this fish occur abundantly in March attached to stones, tangle-roots, old shoes, tin vessels, and, indeed, almost anything convenient. They are found again somewhat earlier (February) at Gairloch and other parts on the west coast. The authors of the *Scandinavian Fishes* broach the idea that the roe of this fish may be fertilised before deposition, and suggest that the serrations on the inside of the breast-fins may be useful to the males for this purpose. There is no reason to suppose that in Britain the eggs are so fertilised; on the contrary, it is evident that they are not fertilised before deposition. As an example we may take a female observed shortly after the opening of the St Andrews Marine Laboratory[1]. This specimen, whose abdomen was distended, had been isolated in a glass vessel, so that its movements were somewhat limited; and it is probable, therefore, that the deposition may have been hastened. It had been observed to be somewhat restless the previous day; and on the 1st March it rested quietly on the bottom of the vessel, and in a few seconds deposited a mass (as large as a duck's egg) of faintly pinkish eggs, keeping its breast-fins in active motion during the process, and then it dashed through the water, sending some of the eggs over the edge of the vessel. The mass of eggs, at first quite soft, though cohering together by a secretion, soon harden, the capsules adhering by facets to each other as in the lump-sucker, so that the egg-mass (Plate I, fig. 6) resembles a spongy structure into which water freely enters, and is retained in considerable quantity even though the eggs are uncovered by the tide, a provision of some importance. They vary in colour from that first mentioned to roseate, orange, straw-colour, and deep red, and have a diameter of about 1·5 mm. to 2 mm. (Holt). The capsule is thick, tough, and resistant, and shows the facets or processes by which it adheres to surrounding eggs (Plate I,

[1] W. C. M. *3rd Ann. S.F.B. Report*, p. 59, and *14th Ann. Report*, p. 181.

fig. 5). It appears minutely punctured, under a high power, the punctures having, as a rule, a more regular (linear) arrangement than in the lump-sucker. Moreover, larger dots occur at intervals all over the surface, resembling those seen in the lump-suckers' eggs removed from the stomachs of young cod. The yolk internally has several colourless oil-globules, from three to nine, as mentioned by Mr Holt, and they vary in size from ·015 mm. downward. The yolk itself is tinted pale brownish or faintly reddish-brown. Mr Holt, who carried on special observations on the eggs of this species at St Andrews, could not make out the passage of the oil-globules through the yolk, as had been described by one of us in the gurnard; but, so far as observed in 1884, there was no reason to doubt that the oil-globules followed the same movements as in other forms. In the developing embryo the oil-globules coalesce, so that but a single large globule remains. In the tanks of the laboratory the eggs are readily eaten by other specimens of the same species.

The development of this form is somewhat slow, especially in cold seasons, so that masses of eggs with advanced embryos are often found in April and even in May. Mr Holt found the larval fishes, on emerging from the egg, 7·5 mm. in length, and this accords with our own experience. The yolk forms a comparatively small prominence ventrally, and the large oil-globule lies at its front inferiorly. 'The head is large and broad; the profile of the snout abrupt; the eyes large and fully pigmented; and the ear-capsules, of about the same size as the eyes, lie close behind them. The mouth is open, but the lower jaw is at first immovable.' The internal organs are well developed (Plate V, fig. 7). The tail in May shows only embryonic rays. The breast-fins are large and fan-shaped. The heart and blood-vessels are in full activity, the returning blood streaming over the yolk, and finally entering the heart. The oil-globule is often on the right of the middle line.

The coloration consists generally of an olive-green hue, a series of distinct black chromatophores over the head, and a few about the base of the breast-fin. They form a broad band on each side of the abdomen over the yolk, and extend from the breast-fins to the vent. 'Pigment of a bright yellow colour by reflected, and orange by transmitted, light occurs also at the base of the breast-fins, on the top of the head, and on the abdominal roof.' The eyes are black with a greenish iridescence. 'In the post-anal region the only pigment is a ventral line of black chromatophores, sometimes very small or absent in the anterior region, and ceasing before reaching the tail.'

The vitality of the larval sea-scorpions is remarkable. They will survive for a fortnight in March, in a small quantity of water, in a glass vessel 2 inches across and 1 inch deep.

On the 10th October, on one occasion, a larval form resembling a sea-scorpion was captured in the tow-net. In general outline it resembled that figured in the 'Researches,' with the vessels coursing over the yolk-sac. The oil-globule remained at the anterior part of the yolk-sac. Small specks of black pigment occurred along the sides of the body, one set forming a row near the upper-lateral region. No distinct coloration was visible on the pectorals. The eyes were iridescent-greenish, like the inner surface of the shell of *Haliotis*.

Hitherto it has been unusual to get larvæ at this season of the year, so that the deposition of such eggs must have been antedated by some months on this occasion—if the interpretation of the nature of the larvæ be correct.

Swarms of the early post-larval sea-scorpions, indeed, just after the absorption of the yolk, about 7 to 7·5 mm. (in spirit), are occasionally captured in the surface tow-nets, as in the Forth, e.g. in March and April. Such pelagic forms have only embryonic rays in the tail-fin. The body and tail are translucent, whilst the head and abdomen have a pale greenish hue with black chromatophores, and the eyes have a silvery lustre. A line of black pigment-specks runs along the ventral edge of the muscle-plates behind the vent almost to the tail.

Mr Holt[1] observed that the lower jaw is movable two days after hatching, and that the vent is open. In our examples, a thickening below the axis of the tail occurred. When six days

[1] E. W. L. Holt, *Sc. Trans. Roy. Dub. Soc.*, v. 2, p. 21, &c.

old the length is 8·4 mm., and the yolk has diminished, while the oil-globule has been elevated to the gullet.

The young forms were kept in the tanks till the 17th day, but development proceeded slowly under the somewhat unfavourable circumstances. On the 7th day they measured 7·7 mm., and during the two or three subsequent days the pigment made great progress, extending behind the vent, and passing from the dorsum down the sides. The chief changes are the straightening of the ventral line from the head to the vent, from the diminution of the yolk, the disappearance of the oil-globule, the increase in the length (forward) of the lower jaw, and the presence of a distinct and broad pigment-band on the side of the body a little behind the vent. The notochord is still perfectly straight at the tip of the tail, and the circulation is much as before. On the 10th day the yolk had disappeared, but the embryonic fin-rays were present only in the tail. The absence of food would, as Mr Holt suggests, suffice to explain the slow progress, but not altogether, since, in the open sea, specimens of 9·5 mm. are occasionally procured in a similar condition, viz., having a membranous dorsal and anal, and only embryonic rays in the tail. Those in confinement differed in having no trace of the ventral fins, and the thickening beneath the tail was better marked in the free forms; spines on the gill-cover were also present.

In specimens of 7 mm. (in spirit) captured in the bottom-net in the bay, the head has much increased in size, the fish is thick-set, and the gill-cover has minute spines. Embryonic rays are well developed in the tail, and a thickening occurs beneath the central axis. The black pigment has largely extended along the dorsum to a line behind the vent, and it is more abundant on the head. Such a form contrasts with the slender and ill-nourished specimens reared in the tanks, in which the abdomen was shrunken and the end of the gut distended, as if the vent were closed. The breast-fins, however, were large.

At the end of April and beginning of May, pelagic forms of from 9·5 to 10 mm. are not uncommon at the surface, e.g., off the Isle of May. The body has now considerably increased in bulk, and a series of sharp spines project from the gill-cover, and two on each side of the occiput. The larval tail is present, but it is bent upward by the development of the true rays inferiorly. The ventral fins appear as minute processes.

In contrasting such a stage (e.g., one 9 mm. in length) with a gadoid, it is easily distinguished from the latter by its shorter snout, smaller mouth, and smaller eye, as well as by the deeper greenish pigment, with a trace of yellow on the head and abdomen. Moreover, the latter is much more densely and somewhat regularly spotted with blackish pigment, the whole having a tessellated aspect. Further, from the greater tenacity of life in the sea-scorpion, the body does not so soon assume the whitish opacity so characteristic of the gadoids; indeed, though perfectly motionless, the heart may be pulsating. The blackish pigment again is confined to the ventral edge instead of passing along both dorsal and ventral edges, as well as some distance up the sides, as in the gadoids.

Except in the tail, the young gadoid of the same size has only embryonic rays in the continuous marginal fin, while in the sea-scorpion a considerable number of rudimentary true rays occur both dorsally and ventrally (10 or 11 dorsally and 6 ventrally). In the anal fin the true rays commence anteriorly. Those in the dorsal begin just above the latter (that is, a little behind a perpendicular line from the vent). No permanent rays appear in the dorsal and the ventral marginal fin of the gadoid, even though the example exceeds in length the cottoid of this stage.

A very evident difference exists in the tail of those of equal length. Thus, the upper and lower elements (epiural and hypural) are more or less equally developed in the gadoids; the ventral series, however, terminating in one or two larger cartilages. The tapering notochord (elementary back-bone) is straight, and extends considerably beyond both series. True caudal fin-rays, moreover, are developing both dorsally and ventrally, giving the tail a peculiarly symmetrical or 'feathered' appearance.

On the other hand, the notochord in the sea-scorpion is somewhat less finely tapered, has a thicker sheath, and the inferior (hypural) elements alone are conspicuous in the form of a large inferior and two upper cartilages. The permanent caudal rays are developed only inferiorly, while the whole dorsal half, and the region extending to the last ray of the dorsal fin, have embryonic rays.

At 11 mm. many are still pelagic (17th May), and show the three anterior gill-spines,—the occipital, superciliary, and nasal spines (Plate V, fig. 10). The ventral fins are minute. The pigment approaches that of the adult stage, only it is not so largely developed. The larval tail is at the upper edge of the organ, and the marginal fin is continuous and has only embryonic rays.

When from 14 to 18 mm. they still occur as pelagic fishes in the tow-nets. The head and body are now larger and more deeply pigmented, the former being entirely covered and continuous with the dorsal pigment, which passes downwards to the cheeks and chin. A bold bar in many exists at the base of the breast-fins, another across the region of the first dorsal fin, and one at the second dorsal, the latter, moreover, extending downward on each side to the ventral edge. The pigment of the two latter bars in some is specially dense, though in others the tint is more uniform dorsally. The head is cottoid in appearance, the superciliary ridge and the occipital tubercles with their spines being conspicuous. Three of the spines on the gill-cover are large, the fourth at the inferior edge being small. The boldness in the demarcation of the pigment gives the fishes a piebald aspect in spirit (Plate V, fig. 8). The larval tail is represented in the smaller forms by the upturned central axis (notochord). True rays now occur in all the fins. The voracity of these young forms is remarkable. One of 16 mm., for instance, in captivity swallowed a young flounder not much shorter than itself, just as the larger examples cleared the young gunnels out of the tanks.

At 22 mm. (27th May, estuary of the Eden), the bar of pigment behind the vent has sent a process backward to the tail, but it goes no further than the basal region. Symmetrical white spots—one dorsal and two ventral—occur in this prolongation. The occipital and supra-orbital tubercles are less prominent, but the supra-nasal are distinct. A large spine occurs on the gill-cover (operculum). The upper spine on the gill-cover (pre-operculum) is largest. The first dorsal fin has 9 rays, the second 15, the variegated pectoral 16, the ventral 3, and the anal fin 13. The caudal has 12 long rays besides four or five shorter at each edge. The chief difference, therefore, between this and the adult is the increase in the caudal rays, but the short basal ones probably disappear during growth. One specimen in July reached 2 inches.

In June they reach 23 to 24 mm., and in July 38 mm., (1½ inch) with adult characters, the first dorsal having 9 rays, the second 16 rays, and the anal still constant at 13.

In the same month one of 88 mm., also in its second year, was captured in Guernsey.

In September specimens 54, 65, and 85 mm. (nearly 3½ in.) occur, the first being considered by Mr Tosh as the young of the season at 5½ months. It would be difficult to separate that at 65 mm. from the same series, but that at 85 is considerably older, probably by a year (or, as Mr Tosh puts it, 1 year and 3 months). The usual arrangement of the spines on the gill-cover in such forms is as follows:—A spine points downwards at the ventral edge of the pre-operculum, two short spines occur above, then the upper long spine, above which is the opercular spine. Two short spines appear on the sub-operculum.

Those of 57 (2¼ in.) and 74 mm. (3 in.) in February represent specimens about a year old, while those of 98 mm. are in their second year or approaching it. One of these (98 mm.) had almost ripe eggs, so that the remark in the new edition of the *Scandinavian Fishes*, that it does not propagate its species until about 150 mm. (nearly 6 in.) long, is not applicable to our country.

Long-spined Sea-Scorpion. (*Cottus bubalis*, Euphras.)

The eggs of this form (Plate I, fig. 4) were alluded to and figured in the *Researches*, and they have been frequently observed since. Moreover, Mr Holt had an opportunity subsequently of studying them at St Andrews Marine Laboratory, and his careful observations and those of Mr Cunningham have been drawn upon for the present purpose. The eggs are found between tide-marks in April amongst tufts of sea-weed, or on ledges of rocks, so as to be partially exposed at low water. The masses are usually flattened, and of a size less than the palm of the hand. The diameter of the egg is 1·70 to 1·88 mm. The capsule is peculiarly corrugated or minutely nodulated, and the yolk has a golden yellow or straw-colour. The oil-globules are numerous, as shown in the figure.

The newly hatched larva (Plate V, fig. 9) is smaller than that of the short-spined bull-head, measuring about 5·7 mm. The choroidal pigment of the eye has a deep blue colour (Cunningham). Yellow pigment occurs on the head and the pectoral region. No black pigment exists on the top of the head, or along the ventral edge behind the vent. The pigment along the roof of the abdomen is peculiarly dark, and has quite a different aspect from that of the species above mentioned. Mr Holt has likewise pointed out that the circulation of the yolk-sac is more complex than in the other species, the blood leaving the liver in at least two and generally in three vessels. The oil-globule lies behind the heart in front and has a diameter of ·22 mm.

In two days the length in confinement has increased to 6 mm., and the yolk is reduced. Black chromatophores occur along the edge behind the vent, which is open, and canary-yellow pigment amongst the black on the roof of the belly. On the fourth day embryonic rays appear in the tail-fin; the length is 6·28 mm., and the oil-globule is reduced. On the sixth day the yolk is still further diminished. Black corpuscles have appeared in the covering of the mid-brain, internal to the ear-capsules and round the vent. The gills show papillæ. At the tenth day the length reaches 6·42 mm., chiefly from increase in the tail, the jaws move freely, an opercular fold is present, and the gills are pectinate. The liver is much larger. Black chromatophores form a conspicuous median dorsal line over the anterior part of the abdomen, and similar pigment appears on the pre-anal fin.

At the 20th day in confinement, increase in length was found by Mr Holt to be *nil*, probably from want of food. All traces of the yolk and oil-globule have vanished. The breast-fins are very large fan-shaped organs. A thickening (hypural) beneath the notochord causes a slight upward bend of the tail. A single process in the upper opercular region (hyomandibular) indicates the pre-opercular armature of the adult.

A specimen of 7·3 mm. procured south-west of the Bell Rock on the 8th August, 1888, may be a post-larval example of this species. The body is short and thick, the two dorsal fins are outlined, but still connected with each other and with the tail by the larval fin. The caudal fin is well formed, but a trace of the larval tail exists superiorly where the tip of the notochord also appears. The breast-fins are large. The ventrals form minute processes. The front gill-cover (pre-operculum) has about four spines. The posterior occipital tubercles have spines, the pair in front do not show them. No turbinal spines are yet visible. The specimen is much shorter than the short-spined *Cottus* of the same age, and the body is deep and somewhat flattened. The identity of this form is still doubtful.

The subsequent stages of this species are still in need of observation. Mr Holt found a form of 10·5 mm. which he doubtfully refers to it. Though it has two pairs of small tubercles connected by longitudinal ridges on the top of the head, it does not appear to be a young *Cottus quadricornis*, since both turbinal and supra-orbital spines are absent, and therefore Mr Holt's suggestion is probably correct, viz. that it is a stage in the development of the long-spined *Cottus*.

In the Irish expeditions of 1890–1891 Mr Holt took a young example of 21 mm. in Jeelin harbour on the 19th May, a fact which shows that the spawning-period is considerably earlier on the West coast of Ireland. On the East coast of Scotland this species spawns somewhat later than the short-spined bull-head—if the interpretation in regard to the eggs and larvæ, by Mr Holt and ourselves, is correct. In the recent *Scandinavian Fishes* the spawning-season is stated to be the end of November and in December; Mr Cunningham again at Plymouth found the period of deposition to be from January to March.

In August a specimen 4½ in. long occurred at St Andrews.

FOUR-HORNED COTTUS. (*Cottus quadricornis*, L.)

In the recent edition of the *Scandinavian Fishes*[1] the spawning season of this species is given as November, December and January in the Baltic. "The roe is deposited, says Sundevall, like that of the Perch, in one single mass; but this is attached to the bottom in water of some depth, possibly even several fathoms. From a piece of roe which Baron Cedeström found in a seine, the young were hatched during the latter half of April. They were then about 11 mm. in length, and their external and internal organs were far more developed than is generally the case in the fry of other fishes. They swam about freely, but soon sought shelter in the roe from which they had emerged." This account is somewhat remarkable—especially in regard to the size of the larval fishes on emergence, and fresh investigations are required.

Post-larval stages of this species have occasionally been obtained in the mid-water- and other nets in and off St Andrews Bay during the last ten or twelve years, but the eggs have never been accurately differentiated if they have ever been obtained. When engaged in investigations at this laboratory in March 1890 Mr Holt concluded that a cottoid larval form which was familiar to us from the mouth of the Forth and St Andrews Bay might belong to this species, since the larvæ of the short- and the long-spined were already known. A certain amount of doubt remains, especially as the eggs have not yet been identified, but as the larvæ have not been linked to other forms, and as no contra-indication is apparent, the suggestion may be allowed to stand. Mr Holt's youngest examples, which were 3 mm. in length and had considerable oil-globules, were dead. A somewhat older form from St Andrews Bay measured 4·08 mm. and much resembled the father-lasher. "The globular urocyst, and the separation of the coalesced ureters from the immediate neighbourhood of the gut appear to be features essentially characteristic of the two forms in their late larval stages." A brownish-yellow mass in the anterior

[1] p. 179.

region of the abdomen represents the yolk with its single oil-globule (now minute). A feature which from the first was most diagnostic was the dense black pigment of the lining membrane of the abdominal roof, and it is outlined by a fringe of yellow. A single ventral line of black chromatophores occurs behind the vent.

Forms somewhat older were caught in the bottom nets at the beginning of May measuring 4·8 mm. (in spirit), and with well marked embryonic rays in the tail. In these as well as in the younger forms a curious separation of the black chromatophores of the abdominal roof takes place.

Mr Holt procured specimens of 6·25 and 7 mm. off the West coast of Ireland; while one of 8 mm. was formerly described in the *Researches*[1]. The deep black patches of abdominal pigment were very conspicuous. The head is greenish and the body comparatively pale. The eyes, as in the common form, are bluish, with a remarkable St Andrews cross radiating from the pupil, the long axis being horizontal (Plate V, fig. 11). Stellate black chromatophores occur on the under surface of the abdomen, a touch of the same pigment at the anterior region of the branchiostegal rays, and a row runs along the ventral edge of the body above the anal fin. One or two specks are also present on the cheeks, and a considerable number over the brain, the latter being bounded by a curved line which joins a median black band in front of the dorsal fin. The four tubercles on the head are distinct, the posterior pair being the larger. The turbinal spines are not visible; but the four on the anterior gill-cover (pre-operculum) are well-marked, the superior being especially evident. The first dorsal fin is only slightly arched, the second is continuous posteriorly with the larval tail-fin, which now lies at the upper angle. The permanent rays give a somewhat conical shape to the tail ventrally. The anal is likewise joined to the caudal. The breast-fins form fan-shaped organs, the rays passing close to the surface of the body. The rays are massive though soft, and, as in the adult, present considerable free portions at the tip. The ventrals are small, and arise somewhat behind the bases of the pectorals.

[1] *Trans. R. S. E.* p. 862.

Another example measuring about 11·5 mm. was procured on the 20th June. A considerable amount of black pigment occurs on the head and cheeks, and a dark area exists at the first dorsal fin, and two behind, as in the common form (short-spined *Cottus*). The breast-fins are large, reaching behind the middle of the body. The ventral fins are still comparatively short. Four prominent spines exist on the front gill-cover (pre-operculum). The four tubercles on the top of the head are well marked, besides a supra-orbital and a turbinal spine. On each side of the dorsal fins anteriorly is the series of elevated scales which are continued backward to the termination of the second dorsal. A somewhat smaller example (10 mm.) is carefully described by Mr Holt[1].

The Red Gurnard. (*Trigla cuculus*, L.)

This species, which is not common on the North-East coast, though frequent on the southern shores, both east and west, spawns about the same period as the grey gurnard. Its eggs have been described both by Mr Cunningham[2] and Mr Holt[3], and have probably been occasionally procured in the tow-nets off the Forth and the neighbourhood. The eggs (Plate I, fig. 10) measure from 1·47 mm. to 1·61 mm.—a considerable variation, while the oil-globule ranges from ·30 to ·33 mm., and is copper-coloured. In the earlier stages, several oil-globules are present, but by-and-by they coalesce, so that, on the escape of the larva, only a single globule remains, and its colour gradually fades. Cunningham was successful in hatching the eggs, and found the larva to be 3·7 mm. long. It bears a general resemblance to that of the grey gurnard, though the oil-globule is not thrust so close to the posterior border of the yolk as in the latter species. The pigment (black and orange or yellowish orange) appears to correspond very closely in the two species.

[1] *Trans. R. D. S.* v. 2, p. 119.
[2] *Jour. Mar. Biol. Assoc.* No. 1, p. 12, 1889.
[3] *Sc. Trans. Roy. Dub. Soc.* v. 2, p. 31, 1893.

The Sapphirine Gurnard. (*Trigla lucerna*, L.)

Though by no means a rare fish, the eggs have hitherto received little attention. Day is of opinion that the breeding-season is during the first six months of the year. Couch found mature ova in December and February. Risso gives the spawning-period as spring. In July (18th) the ovaries were much enlarged, the eggs having an average diameter of ·031 inch. Even so late as the 14th September some ripe eggs have been found in the ovaries at St Andrews.

The Grey Gurnard. (*Trigla gurnardus*, L.)

Amongst the pelagic eggs of numerous species found on the East coast, that of the grey gurnard is perhaps the most conspicuous, not only because of its occurrence in great numbers but also because it has a wide distribution in point of time. Though not one of the earliest to put in an appearance, it is found fairly frequently in April and in some parts even earlier, and from this month onwards through the summer to the end of August it increases in numbers, so that in June it is by far the commonest egg, though that of the sprat is found with it in great quantities. From this it will be seen that the spawning-season of the gurnard extends over a considerable period, a fact which is further borne out by an examination of the structure of the female reproductive organs. In this fish, as in the cod and some others, the ovaries ripen by degrees, so that very rapid extrusion of all the eggs is not likely, but they are discharged in sections as they become ripe. Hence if a female gurnard be examined in May, the ovary will show a number of ova in different stages of development, and, as one observer states:—"In the gurnard the gradual process of ripening and the co-existence of perfectly mature and microscopic ova is even more marked than in the whiting, and shows that the spawning-process is a prolonged one," though it is possible that the microscopic forms are not all utilised the same season.

A single ovary contains roughly about 120,000 eggs, so that the gurnard is not one of the most prolific of the 'pelagic' fishes.

The male organs in such as the sapphirine gurnard, mentioned by Mr Holt, are proportionally large, so that some resemble females by the distension of the abdomen.

As regards the spawning-habitat the gurnard often seems to frequent the inshore waters. Mature gurnards are most abundant just outside the three-mile limit, though they are also found in the shallower parts of St Andrews Bay and high up the Frith of Forth. The distribution of the pelagic eggs themselves, as found by surface-netting, agrees with these facts, the eggs of the gurnard and the sprat being found further up the Frith than any other pelagic eggs. In the autumn the 'spent' fishes appear again to migrate seawards, so that the migratory habit of the gurnard is to some extent the reverse of that of the cod and the haddock.

One observer states that the gurnard spawns twice every year, once in the winter and once in the summer, but although there is an isolated case of the egg of the gurnard occurring in Moray Frith in January, yet an examination of the females, as above alluded to, gives no indication of spawning taking place twice every twelvemonths.

The females of this species are considerably larger than the males, a feature in which they agree with the cod and haddock. In the salmon the same occurs, the difference in this case being due to an earlier maturation of the male: whether the difference in comparative size of the two sexes of gurnards is due to the same cause cannot be stated with certainty.

The egg of this fish (Plate I, fig. 9), which closely resembles that of the red gurnard[1], is large, being 1·52 mm. in diameter, with a large (·28 mm.) and conspicuous oil-globule of a smoky or sometimes salmon-hue. It is less delicate in appearance than those of the cod, rockling or flounder. The perivitelline space is often fairly large before the egg is fertilised, but after this process the germ usually swells up and comes in close contiguity with the egg-capsule.

The period of incubation varies from eight to fourteen days

[1] J. T. Cunningham, *Jour. Mar. Biol. Assoc.* I. IV. s. p. 11.

in May to six days in June or July, the greater mean temperature of the latter having the usual effect of hastening the development.

The yellowish pigment is developed both on the body and the yolk-sac in the egg before hatching, but it appears somewhat later in the embryo in May than in the gadoids and flounders. It consists of pale yellow spots which have a delicate sea-green tinge in certain lights. They are sparsely scattered over the trunk proper, but form a rude line along the back, and an undulating line along the sides, around the eyes and over the yolk-sac. The pigment in the latter is preceded by pale protoplasmic stellate corpuscles.

The young larva when just hatched (Plate V, fig. 12) is a glassy transparent form with a large yolk-sac, at the posterior border of which is seen the tinted oil-globule, surrounded by a thin layer of protoplasm. It measures about 3·8 mm. The larval fish is conspicuously marked with pigment of two kinds. The dull yellow, sometimes greenish, spots already referred to in the embryo, are scattered over the head, back and abdomen, but are absent from the tip of the tail. The front (dorsal) part of the embryonic fin is picked out, at its edge, by yellow spots, with which are mingled a few black ones, forming a row which invades the fin further behind and meets the pigmentation of the body just in front of the tail. There is a similar but less distinct line on the ventral part of the marginal fin. The pectoral fin has a peculiar arc, of black and yellow stellate spots, which is very striking. Other larval fish described later on have the same banded arrangement upon the pectoral fins. The whole of the black pigment is later in appearance than the yellow, and then to some extent follows the lines of the latter colour on back and fins and is diffusely scattered over the body and yolk-sac in minute black dots.

Lastly, the pigment, besides being distributed over the surface of the larva, as detailed above, spreads out over the surface of the yolk, which presents scattered yellow and black chromatophores. In this feature the gurnard agrees with the whiting, sole and ling, whilst, on the other hand, it disagrees with the cod, haddock and rockling. The pigment-corpuscles appear to be really in the protoplasmic layer enveloping the yolk, and differ from those found on the body of the larva by the fact that they are much branched, and often anastomose. A good deal of individual variation in the amount of the pigment exists, probably because some are hatched at a slightly earlier stage than others. The larva, as in other species, hangs in the still surface-water of vessels with the yolk-sac uppermost, often with the head downwards. During the next three or four days the pigmentation increases, the individual chromatophores become branched, and the yolk-sac rapidly diminishes.

One remarkable feature in the early stages of the grey gurnard is the great development of the pectoral fins, as, indeed, Cunningham also found in the red gurnard. This is evident upon the second day, and it is accompanied by a marked decrease in the region between them and the embryonic ears. The snout also becomes prominent, and the mouth is open from the first, although the gullet does not acquire a lumen till later.

At 5 days the little fishes have become active and are about ·165 inch long. The eyes have black pigment, with a greenish lustre. The yellow colour is conspicuous about the head, the yolk-sac, the pectoral fins, the anterior dorsal region and the angle of the lower jaw. The black colour is found in abundance at the base of the abdomen, and a few spots occur on the snout and ventral border of the muscle-plates. The pectoral fins have now developed into a pair of large fan-like paddles projecting at right angles to the body and are concave backwards, forming efficient organs of locomotion.

During the following days there is an increase of the black pigment and a still further hypertrophy of the pectoral fins. The mouth still gapes widely, the gurnard being a fish which essentially develops with its mouth open, a habit which gives the larva a diagnostic appearance, and no doubt subserves respiration to a great extent when combined with a rapid forward movement of the body in the somewhat quiescent water of the vessels in the laboratory.

The last stage reached in confinement is about 3 weeks old; in this we note the huge pectoral fins, the yellow pigment on the latter, the head, and the yolk-sac. The marginal fin is still continuous, and a few pigment-spots are dotted over it and upon the tail.

The next stage, about ·235 inch long, is represented by specimens caught in the sea on August 31st, which clearly belong to the same series. The head, with eyes and brain, is large, and the scoop-shaped indented snout is prominent. The yolk-sac has nearly disappeared. The pectoral fins have still further increased and the tail shows signs of becoming heterocercal by the greater development of the lower rays. By this time the little fishes have, even though so small, left the surface-water and taken up the habitat of their older brethren, namely the still water of the open sea at a depth of about 25 fathoms.

With a further growth in length, the head and snout become proportionately larger and longer, and the little gurnard is protected by the development of a number of conspicuous spinous processes which make it a prickly morsel for predaceous enemies. Two spines on the back of the head first appear, and later, others are seen upon the operculum, the angle of the lower jaw and the facial region.

In the large pectorals there are thirteen fin-rays all joined by membranes, but as the fish progresses in size the three most ventral rays separate from the others and eventually become free, both from the pectoral fin and from each other. They form the three pairs of moveable 'feelers' which are a well-known feature of the adult gurnard, and which have been carefully investigated at St Andrews by Mr H. C. Williamson[1]. This is a good instance of the repetition, in the development of the individual, of a modification in structure which the species has adopted in the course of time. Thus it is believed that the gurnard is descended from ancestors which had all the fin-rays united together as in most fishes, but that the three ventral rays, being gradually specialised as feeling organs, became separated from the rest until at last the free condition of these rays, in the gurnards of the present day, was reached. Hence we find that the young gurnards pass through the

[1] Vide 12th Report Fishery Board for Scotland, p. 322, Plates 13—15.

same stages on their way to the adult condition. Instances of this law, even more striking, will be noticed in the life-history of the flat fishes.

It is still an undecided point as to how far the gurnard uses its three pairs of feelers only as tactile organs, or combines with this function that of supporting the weight of the body when at rest, and of assisting locomotion.

Returning to the young forms of gurnards, fig. 13, p. 57 shows a post-larval stage of about $\frac{3}{5}$ inch in length. The tail is markedly heterocercal and the enormous pectoral, and small ventral, fins are noticeable. The marginal fin has a dorsal indentation, which indicates the future splitting up into first and second dorsal fins, though only embryonic rays are present at this stage.

Black pigment has increased over the pectoral fins, head, cheeks and abdomen. At this and later stages there is often to be found attached to the head a young form of the parasitic crustacean, *Caligus*.

Further development proceeds in the direction of the breaking up of the marginal fin to form the caudal, the dorsals and the anals, and the appearance of adult fin-rays ; the ventral fins also elongate till they reach beyond the vent.

A post-larval gurnard at this stage (Plate V, fig. 13) is one of the most grotesque little animals which one meets with, its long angular snout, large greenish eyes, huge pectoral fins and numerous little spines all adding to its unique appearance. The huge pectoral fins form a drapery for the entire body when folded back, only the tip of the tail extending beyond them. They are indeed proportionally as large as in the southern flying gurnards, but in these the fins reach full development only in adult life, while in the young stages they are comparatively small, exactly the reverse happening in the grey gurnard of our seas.

At $\frac{3}{4}$ inch, the black and brownish pigment-spots, dusted over the pectoral fins, may be noticed to have a tendency to group themselves into three transverse bands which later become very marked.

At a little over $\frac{4}{5}$ of an inch, the little gurnard assumes the leading adult characters (Plate V, figs. 14 and 15). The three pectoral rays are free; the general pigmentation has increased, probably correlated with its change of habitat to the shallower inshore waters; while the pigment upon the pectoral fins is conspicuously disposed in three bands, a basal and two distal, and that on the hinder part of the body forms a pair of prominent V-shaped vertical bands. The head and dorsal fins are also boldly marked.

Later, the spines on each side of the dorsal fin and on the lateral line are distinct, and the membrane connecting the base of the three free pectoral rays gradually disappears.

During September and October little gurnards from $\frac{1}{4}$ to $\frac{1}{2}$ in. in length are found, and again at the end of October a specimen about 29 mm. or $1\frac{1}{8}$ inch occurs. In this specimen the pigment shows the same general arrangement as in the last (Plate V, figs. 14 and 15) but is more abundant. The tail has brownish pigment-spots dusted over its distal half and a thick mass of brown pigment at its base, and these two areas are divided by a broad transverse band without pigment, so that the general effect is that of two dark bands and a light one crossing the rays of the tail. The back and sides have blotches of brownish pigment and that on the dorsal fins is black. A dense black blotch is found on the first dorsal, and two faint black longitudinal lines run on the second dorsal fin. The barred condition of the pectorals is no longer evident, for the deep black pigment covers the whole fin. The pigment has increased under the eyes. Four longitudinal rows of spines running down the trunk are now conspicuous, two on the back, on either side of the dorsal fins, and two along the lateral line. The pectoral fins now bear a smaller proportion than heretofore to the size of the fish and approach those of the adult.

A young gurnard of 2 inches caught at the end of November shows the black pigment confined to the distal half of the pectoral fins, and the first dorsal fin has the same change, the black pigment being now concentrated in one large spot. The pigment of the body is also more diffuse and closely resembles that of the adult.

A specimen almost identical in size and appearance occurs in June, together with two others, 3 in. in length. In these the first three rays of the first dorsal protrude beyond the fin-membrane as in the adult; they are rigid and sharply pointed. The depth of the body is greatly increased and the head is smaller in proportion.

The next stages occur in July, still on the bottom, and are about 3 to $3\frac{1}{2}$ in. long. Their appearance and structure are practically those of the adult.

As regards the rate of growth the little gurnards appear to grow fairly rapidly, and by June of the following year two series are noticed, some ranging from $2\frac{3}{4}$ to 3 inches and others from $4\frac{3}{4}$ to $6\frac{1}{2}$ inches. Another series is represented by little fishes ranging from $4\frac{1}{8}$ to $6\frac{1}{8}$ inches in length and occurring a month earlier than the above (*i.e.* in May). At present we have no definite means of confirming the supposition that these are all fishes which were hatched during the previous season; but this is probably the case, in spite of the great disparity of size. The latter feature may be largely due to the lengthened period during which the gurnard spawns. Thus, larvæ hatched at the end of April might easily be three months older than those hatched at the end of the spawning-period, which, placing them under more advantageous circumstances for their earlier development, might, apart from the mere difference in age, cause great disparity of size in the following summer. More data are however required before one can pronounce with certainty upon this point. Thus, at the end of August, certain young gurnards range from $\frac{1}{4}$ to $\frac{3}{4}$ inch and of course differ in point of development to the same degree. They are all of the same season's growth, but whereas the former are a few weeks old, the latter must have been hatched in the earlier part of the spawning-period. Again at mid-September specimens of $1\frac{1}{2}$ inch are found, which must also be regarded as of the same season's brood. We are thus presented with a series of gurnards at the end of summer ranging from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch or more, which vary from an age of a few weeks to one of nearly six months (April to September).

Taking this series as a basis, those in May referred to above ($4\frac{1}{8}$ to $6\frac{1}{8}$ inch) would be from 10 months to 13 months old, whilst the series of $2\frac{3}{4}$ to 3 inches occurring in June may be from 9 to 10 months and the second series in the same month ($4\frac{3}{4}$ to $6\frac{1}{2}$ in.) would probably contain individuals from two broods, the smaller being about 14 months and the larger 26 months. There is still uncertainty, however, on these points.

The curve of growth from specimens measured by Mr Williamson, of this Laboratory, gives an average length of 4 inches at the age of one year and of $6\frac{1}{2}$ inches at two years, which is increased to 9 inches or more at the end of the third year. It is probable that the gurnard, like most food-fishes, comes to maturity during its third year or a little later. The number of females appears to be in excess of the number of males in the proportion of 4 to 1 and the male is, on an average, slightly smaller than the female.

The Armed Bull-Head Family. Cataphracti.

The Armed Bull-head. (*Agonus cataphractus*, L.)

No form is more familiar in sandy bays in the naturalist's, or small-meshed, trawl than this species, yet its spawning was more or less unknown until recently. Couch gives nothing more than that the spawning-period is stated to be spring; while Day describes a female, 5 inches long, from Southend, in February, as having its comparatively large eggs nearly ripe. In the *Researches*[1] it was mentioned that the females caught in the sprat-nets in the Tay showed nearly ripe ovarian eggs on the 16th December, and that they had a dull golden or dull yellow colour, their diameter being ·07 in. and that of the oil-globule ·0216 in. The capsule is minutely dotted with punctures arranged in linear series, and the surface has well-marked reticulations (Plate I, fig. 8). It is added that the species seems to spawn from January (or perhaps December) to April, females with nearly ripe ova occurring in March.

[1] McIntosh and Prince, *loc. cit.* p. 674.

The eggs are often deposited on the rocks at low water-mark in straw-coloured masses.

In the recently published *Scandinavian Fishes*[1] the authors observe that "the males are so rare that neither Kröyer nor Ekström has met with a full-grown example; nor, during late years, has the Royal Museum received a single specimen. It is probable that it is only during the spawning-season that they live in so shallow water as to be in any danger from the nets used in shore-fishing. The spawning-season is in spring; in March and April, or the beginning of May. We have no information as to the way in which the roe is deposited, or the development of the fry." It is also mentioned that Kröyer estimates the number of eggs at 3,000. So far as our observations go the males are by no means rare, and they accompany the females into the shallow water, and pass into the estuaries of the Eden and the Tay. The remarks published on the subject have escaped the notice of the authors.

The occurrence of small masses of ova of this species, at the beginning of October, considerably extends the spawning-period. They are procured at low water near the pier-rocks at St Andrews, attached to the roots of tangles and passing into the interstices. The eggs measure from 1·7526 mm. (·0705 inch) to 1·9050 mm. (·075 inch), showing that the ovarian examples, mentioned in the *Researches*, as indeed had often been observed, were nearly ripe. Each egg at this date (to take an instance on 1st October) presented a large oil-globule and an advanced embryo. The circulation was in active operation on the 27th November, the exterior of the egg being, further, coated with many parasites. In January and February the water containing the eggs was frozen, and remained so nearly a month, yet, on the 2nd March, some of the embryos were alive, and, though the water could not be changed, as the pumping apparatus was under repair, were safely hatched. The remarkable hardihood of such eggs is in contrast with pelagic ova, which, as a rule, would have been killed.

The egg-capsule (Plate I, fig. 7) is very tough, and rebounds from the needle under pressure like a ball of india-rubber.

[1] *op. cit.* 210, quoted *Rept. S. F. B.*

It is thus difficult to extrude a perfect embryo. Under a low power the torn edge shows layer upon layer of the secretion.

The larva immediately after hatching closely corresponds with that captured in the bay, and figured by Prof. Prince (*Researches*, Plate XVIII, fig. 11). The body is about 7 mm. long, the tail, which has embryonic fin-rays, being somewhat longer than in the sketch. The head has large silvery eyes, with greenish-yellow pigment behind them, and around and below the widely-open mouth. The snout is blunt, and the ear-capsules large. The trunk, generally, is dotted over with the same greenish-yellow pigment (ochreous by transmitted light), which is also present in streaks on the basal region of the breast-fins, on the yolk-sac, and on the prominent cone at the vent. The three dorsal patches in the marginal fin are distinctly separated, the first being small, and nearly in a line running upward from the posterior border of the vent; the second about the widest part of the fin, and the third about the posterior region of the same dilatation. In numerous examples obtained in the tow-net in March the three yellow dorsal patches had opaque-white tips, thus giving them a striking aspect. Opposite the two latter is a corresponding patch ventrally. A similar touch of yellow occurs at the commencement of the tail. Numerous stellate black pigment-spots are present on the yolk-sac, a few on the breast-fin, and a series along the dorsal and ventral margins of the body as far as the third patch of yellow on the marginal fin. One or two occur on the border of the marginal fin, and a considerable number in the ventral patch of yellow (second) in the latter, while only a very few are found in the dorsal patch opposite it. Two exist in the ventral touch behind the former and only traces in the dorsal patch opposite. One or two chromatophores also occur ventrally in the patch at the root of the tail. The black pigment would seem to be better developed ventrally than dorsally.

The larval examples appear in the various nets in the beginning of April, and measure 7 to 8 mm. in length. They soon become abundant, especially in the bottom-nets, their condition being represented in Plate VI, fig. 1. As they get a little older their length seems to diminish rather than increase, and the black chromatophores occur on the cheeks. The bases of the breast-fins show rows of them springing from the distal edge of the basal process. The fin-rays everywhere are still embryonic. The sides of the body from the tips of the breast-fins backward almost to the tail show a series of isolated black chromatophores arranged in a double row, viz. towards the dorsal and the ventral edges. A group of similar pigment-specks characterises the median or wider part of the marginal fin dorsally and ventrally (region of the dorsal and the anal fin). On the sides and ventral surface of the abdomen the same black corpuscles are scattered, and they run along the ventral surface to the base of the tail. A slight narrowing—dorsally and ventrally—is evident in front of the tail, which likewise has only embryonic rays. The vent is very prominent, and in front of it another projection occurs—a feature characteristic of this form. The notochord (rudimentary back-bone) is quite straight.

When 6 mm. in length (in spirit), and thus shorter than the larval form, as in the case of the paradoxical frog of North America, a great change occurs in regard to the surface, e.g. on the 19th April. The fish is now considerably broader and thicker, and more densely pigmented on the ventral than the dorsal surface, as in the dragonet and other forms, and some specks also are evident behind the breast-fins. Rows of sharp and slightly curved spines pass along the dorsum, on the lateral crests of the head and on the gill-covers. True rays appear on the lower part of the tail, besides a basal thickening (hypurals); and permanent rays are also developing in the breast-fins.

When about 8 mm. long, as in the end of April and beginning of May, the head has now acquired a predominance in bulk—from its elevated dorsal (occipital) and ocular ridges, its spines on the gill-cover, and a tendency to the occurrence of tubercles generally. The spines on the trunk and abdomen are prominent. All these are much more developed in proportion than in the adult. Slight papillæ on the chin mark the future 'cilia.' The head is boldly differentiated from the slender body by the huge breast-fins which project outward like a pair of fans. The black pigment on the under surface is less marked, except at the vent. A V-shaped series of these specks occurs at the breast-fins. The larval tail with the up-turned notochord is still present above the permanent caudal. The dorsal and anal fins, in which true rays are developing, are connected by a broad marginal fin with the tail, and are not so distinctly differentiated as in Prof. Prince's figure (Plate VI, fig. 2). No trace of ventral fins yet exists. In colour this stage approaches the figure just mentioned.

When 12 mm. long (in spirit) the breast-fins are larger, so that they form great fans which fold backward and envelop nearly a third of the body, like those of the young gurnard. Moreover, while they are boldly speckled with black, the sides of the body which they cover when adpressed, are pale. The ventrals (pelvic fins) are now present on the flattened abdominal surface. The head reminds us of that of the Moloch lizard of Australia from the great development of spines and tubercles besides the ocular and occipital crests. The double row of dorsal tubercles in the adult is here represented by prominent rows of soft conical spines and so with the two lateral and abdominal rows, the latter making the sides coarsely dentate. Only papillæ are still visible on the chin and neighbouring region (branchiostegal). The permanent rays of the caudal are complete and the larval tail at the upper border has disappeared. This stage is also somewhat less than that figured by Prof. Prince but it resembles it in coloration. The little fish is a truly pelagic one and finds safety and food amidst the swarms of minute forms carried about by every current.

Those from 14 to 18 mm. (May to July), which are also truly pelagic, fall under the stage represented in Prof. Prince's figure (Plate VI, fig. 2). The spines retain the character of the previous (12 mm.) stage, though they are now considerably harder. Thus from the occiput to the tail the body is armed with four lateral rows of tooth-like processes which are directed backward. In those which have reached 18 mm. the breast-fins seem to be shorter, from the elongation of the body. The papillæ on the chin are longer, but do not project much. The chief coloration is fine chrome yellow with black, especially on the breast-fins, spines and dorsal-fins. In the breast-fins the yellow pigment follows the line of the rays, with black points here and there, the intermediate regions being yellow and black.

Some a little older reach 19 mm. towards the end of May, and are stouter and hardier fishes with a greater development of dark pigment on the dorsum, while three deep brown bands, separated by pale bars, occur on this region of the slender body. The cephalic ridges are prominent and the anterior dorsal spines are large and powerful. The papillæ under the chin show little change. In specimens of this length (19 mm.), with the huge fan-shaped breast-fins, obtained from the townets in the open water offshore, in the midst of a vast assemblage of the pelagic stages of other fishes, the spines are remarkably acute all over. On the other hand, examples of the same length, captured on the bottom within the estuary of the Forth, already have blunt spines throughout, the cephalic ridges flattened and the general aspect more closely like that of the adult, especially in regard to the dense greyish pigment on the upper surface. The breast-fins, however, are much larger, but the 'cilia' beneath the chin are short. The black bar on the second dorsal, and on the anal fin, is very distinct, while in spirit the first dorsal is pale.

The young armed bull-heads reach 25 to 26 mm. at the end of June and beginning of July, and the pigment-bars of the body are distinct. The ventral fins are more elongated. The dorsals are variegated with black pigment (in spirit) and the bar still occurs in the anal. The tail-fin is likewise variegated. The authors of the *Scandinavian Fishes* observe that Kröyer thought the young reached 90 to 100 mm. in September, but the captures hitherto made in this country do not seem to corroborate this opinion. It is more likely that the specimen of 32 mm. in the Royal Museum at Stockholm was a large example of that season, just as that of 50 mm. in December would be an older form of the same series. Those procured by Ekström in spring on the coast of Bohuslan, and measuring 80 to 100 mm., were probably a year and some months old.

The next stage, which is separated by a considerable gap from the foregoing, is that procured in May of the following year, and which is considered by Mr J. R. Tosh in his paper[1] as one year and three months old. It measures from 50 to 67 mm. (in July) with marked adult characters, such as the flattening of the ridges on the head and of the spines on the body, the prominent condition of the nasal and opercular spines, the barred appearance of the breast-fins and their proportionally smaller size, and the bleaching of the anal fin. Other features now present are the variegated condition of both dorsals, and the pale border to the darkly-tinted caudal. The filaments on the chin and adjoining region (branchiostegal) are now considerably longer. In July, those of the same series reach from 67 to 76 mm., and in December 67 to 87 mm., and it may be that those of 110 mm. pertain to the same group, making the age, according to Mr Tosh, of 1 year and 10½ months in the latter case (110 mm.). Well-grown female adults of 138 to 144 mm., with ripe eggs in December, are probably, as the author just quoted says, about 2 years and 8 or 10 months old.

The life-history of this species seems to be as follows:—The adults haunt the sandy flats of the bays and estuaries, and at the breeding-season leave these to deposit their eggs amongst the roots of tangles. From the eggs issue larvæ at an advanced stage of development, which soon become brightly coloured and assume a pelagic existence for a considerable time; then they settle on the bottom like their parents. Meanwhile, however, they have been carried to new districts—it may be at great distances from their birthplace.

The Angler Family. Pediculati.

The Angler-Fish. (*Lophius piscatorius*, L.)

This species, also called the Frog-fish, is somewhat isolated by its peculiar structure. Its huge gaping jaws, large flattened head crowned by three free fin-rays of a peculiar shape, the

[1] 12th *Ann. Rept. S. F. B.* Part III, p. 384.

single gill-opening on each side and the short tapering tail are all features which give the angler-fish a unique appearance. The stories concerning the habits of this fish are full of interest but are scarcely in place here.

It comes under the category of a food-fish and is treated in a similar way to the wolf-fish. The head is cut off and only the trunk is sent into the market. This is sold under the name of 'croan' and sometimes of 'John Dory,' a name that of right belongs to a very different fish. Donovan states that its flesh is 'delicate, like that of a frog'! whilst Couch pronounces it to be delicious. Parnell states that 'the flesh is considered good, especially near the tail.'

The angler-fish belongs to that group of fishes which have floating (pelagic) eggs and agrees with most of this group in that the number of eggs carried by one female is great (Thompson gives 1,420,000 and Fulton 1,345,848) and in that the females are larger than the males.

The eggs, however, do not float separately in the open water but are surrounded by, and packed closely together in, a mass of mucus, and carried about by the currents, as in the case of *Fierasfer*. Baird states that the floating sheet of egg-laden mucus may be from 60 to 100 feet square; Agassiz describes the same as a gigantic band 12 or 13 yards long, of a violet grey colour and somewhat blackish, from the pigment of the contained embryos; Prince describes a specimen from the Frith of Forth 12 yards in length, from 6 to 10 inches broad and $\frac{1}{10}$ inch in depth; each egg is about $\frac{1}{12}$ inch in diameter, so that the band appears to be, so to speak, only one egg thick.

It is a peculiar accidental coincidence that the frog and its allies have eggs enclosed in masses or bands of mucus, and Prince also compares the young frog-fish larva in external appearance to the larvæ of Amphibians. The later larva and even the adult have a certain amount of superficial resemblance in shape to an Amphibian tadpole, which latter fact probably gave rise to the name before the features of eggs or larvæ were known.

The large, floating masses of eggs are somewhat rarely met with in comparison with the abundance of the adult, and Day and others have noticed that "considering the wonderful number of eggs they deposit, but the comparatively few young that are seen, they must be subject to some wholesale destruction as fry, or else when in the ova state." The masses are sometimes caught by the ropes and nets of the salmon-stake nets off the East Rocks at St Andrews.

The ova sent to the St Andrews Laboratory were examined and described by Prof. Prince, and the larval forms up to fifteen days after hatching were followed. The very early stages of development have yet to be described, the eggs noted above containing embryos at an advanced stage (Plate I, figs. 11 and 12). The young embryos differ very much from the type of pelagic embryos found among the Gadoids and Pleuronectids. They are short and stunted with a stout obtuse head, and a 'dagger-shaped tail only partially encircling the yolk.' The blunt outline of the head is caused by the enormous optic lobes of the brain. The whole character of the larva recalls the 'robust embryos of Teleosteans with demersal eggs and a rich perivitelline circulation.' There is a great aggregation of black pigment, mainly covering the brain and spinal cord and the intestinal region of the trunk.

Fig. 3, Plate VI, represents the appearance of the newly-hatched larva. In it we can note the characters above indicated and also the peculiar rounded yolk-sac with a conspicuous oil-globule situated at the posterior end. This globule is covered with a mass of protoplasm in which are a number of large black pigment-spots. Another feature of the larval frog-fish not so well seen except in sections, is a very abundant development of serous spaces just under the skin.

By the fifth day after hatching (Plate VI, fig. 4) the yolk-sac is considerably reduced, and the head stands out more clearly from it: the body is more elongated and the first dorsal spine commences to appear. The ventral fins are very conspicuous as rod-like bodies of immense length, the pectorals being also present but small. The flattening of the larva dorso-ventrally is not yet very evident. During the next few days the first two free dorsal rays become very prominent as elongated filaments above the head, the third being smaller.

The serous space above the head becomes distended. The ventral fins are also long and filamentous with a second short ray appearing at the base of the first. Plate VI, fig. 5, shows these features in the post-larval form 15 days after hatching, and in views from above it is apparent that the flattening of the head and trunk, which is so characteristic of the adult, has already taken place to some extent. By this flattening the eyes come to lie completely upon the dorsal surface, and look upwards. At this point one reaches the stage where the post-larval phase of development succeeds the larval, and the young fish no longer has yolk from which to obtain its supplies of nutriment. It is difficult in tanks to provide the suitable food and surroundings, and hence our knowledge of the further stages has to be gleaned piecemeal by the tow-net.

Here we encounter a peculiar developmental feature of the angler-fish, for during all the continued trawlings of the East coast waters which have been conducted for the last few years,—one and only one post-larval stage of the angler has been forthcoming. This curious little fish has been described in detail elsewhere[1] and is figured in Plate VI, fig. 6. As will be seen it differs in several important respects from the 15-days-old larva. It was caught in the mid-water net, 15 miles off the Isle of May, at a depth of 25 fathoms. It is somewhat over $\frac{1}{4}$ inch (7 mm.). The large flattened head and tapering little tail give it a tadpole-like aspect. The gape is large and the snout very blunt—with a median notch. The eyes are large and round and look directly upwards. Part of the continuous embryonic median fin is still present, and the paired pectoral fins are enormously developed, stretching backwards and outwards as two fan-like processes; the ventrals on the other hand are small, and although broken, appear to have been poorly developed, a feature in marked contrast to the condition of the pectoral and ventral fins of the 15-day larva, where their relative sizes and importance are exactly reversed. The gill-slits are still large and long and differ greatly from the little contracted pore-like apertures of the adult.

From these observations it will be seen that there are

[1] *Trans. R. S. E.* vol. 35, pt. III. p. 869.

important gaps in the stages of development both between this post-larval form and the earlier stage, and between the same and the adult. The well-known ichthyologist, Day, states that 'the young of these fishes when alarmed seek for shelter in the branchial pouches in the axilla of the pectoral fin.' Such a habit must apply to a later stage than fig. 6, when the pelagic habit has been given up. Another observer has asserted that the food of the frog-fish is stowed away temporarily within the gill-pouches: the question naturally suggests itself—can the presence of young anglers in the parental gill-pouches be explained in this way? All accounts of the voracity of this fish would lead us to suppose that it would not refrain from feeding upon its own young.

On the other hand we do not know upon what observations the deceased author based his statements: the above explanation would only apply if his remarks rested simply upon the *presence* of young anglers in the gill-pouches of the captured adults and not upon direct observation of the habits of parents and young. Fishes with pelagic eggs are generally characterised by an entire absence of all parental instincts as displayed in the care or protection of the young, and the latter have to make their way in the world with nothing for which to thank their parents but their mere existence, so that from the fact that the ova of the frog-fish are pelagic we would expect that the young would grow up quite independently of their parents. The eggs, however, although pelagic have one feature characteristic of demersal eggs, namely, the mucus enveloping them in a common mass. The larvæ also have certain features in common with demersal larvæ, as stated above, so that to some extent the eggs of the angler form a type transitional between the pelagic and the demersal. It is possible that they may have been demersal in the earlier history of the species, but have secondarily acquired a pelagic habitat.

Valenciennes describes the young fish, 2 inches in length, as having long pectoral and ventral fins, with some of the rays of the former extending beyond the fin-membrane. The dorsal spine also had more numerous and longer tentacles than in the adult.

There seems to be a great deal of uncertainty concerning the stages between the post-larval fish already described and figured (fig. 6) and the stage at which the adult characters are assumed.

Both Day and Günther in their treatises give figures of a young angler-fish which agree the one with the other. The former author remarks, 'in the young the head is broader than long, but less depressed than in the adult. The depression increases with age while the spines of the first dorsal fin have lateral soft-branched enlargements along their anterior and posterior edges.' Günther also observes that the 'first dorsal spine bears a ciliated bifid appendage and the next four rays are of a racemose feathered type. There are huge ventrals with four free rays, extending to behind the tail.'

This description to some extent agrees with that given by Düben and Koren of a young angler from Norway which had the first dorsal spine terminating in a transverse cylindrical knob, provided with cilia, and being scarcely above half the length of the second spine. This young form so differed from the adult angler that the above-mentioned observers supposed it to be a separate but allied species and even gave it the name of *Lophius eurypterus*.

The gradual broadening and flattening of the head spoken of by Day is a process we should expect to occur at quite a late stage of development as being a feature in which the angler differs from the general Teleostean type, and which has been acquired comparatively recently in correlation to its environment; the peculiar feathered tentacles and the enormous ventral fins, on the other hand, must be post-larval characters of a transitory nature as they are not found in fig. 6 and are also absent in the adult. The long ventrals are present at the age of 15 days. One cannot, however, pronounce a definite opinion upon this point until more certain knowledge is obtained.

The rarity of the post-larval and young forms when compared with the common occurrence of the adults only tends to the supposition that there must be some element in the environment or habit of these stages of which we are at present in ignorance.

The next stage met with during many years' observations measures $5\frac{1}{2}$ inches, and was tossed on shore after a storm in March. Unfortunately it had been considerably injured by gulls, and also partially dried. The head at this stage appeared to be more elongated than in the adult, and the spinous processes were more conspicuous. The three long anterior spines of the first dorsal were well developed. The teeth were long and sharp as in the adult and similarly arranged, while the mucous membrane of the tongue and that within the lower jaw was tinted brownish. The tip of the lower jaw seemed to be somewhat more acute than in the adult. Both pectorals and ventrals had at the free edge a series of long white elastic processes (the tips of the rays), which were all the more conspicuous in the pectorals from the deep brown colour of the adjoining region dorsally and the blackish belt ventrally; whereas in the ventral fins it was the outer aspect which was blackish, the inner being whitish. The long fin-rays of the younger stages had thus been considerably modified to suit life on the bottom, the elastic nature of the tips of the rays and the tough integument intervening being adapted in a most efficient manner for locomotion on soft sand. From the colour of shreds of skin which here and there remained the frog-fish of this size is a brilliantly tinted form. Such an example is probably about 9 or 10 months old.

A young specimen $7\frac{1}{8}$ inches long was trawled on the 17th February, and another $6\frac{1}{4}$ inches in length occurred in May; both they and the preceding probably belong to the previous year's brood, but this is conjectural.

The adult is found as long as 4 or 5 feet, but data with regard to its rate of growth are not to hand.

This much with regard to the habitat we can say with certainty, namely, that the eggs are pelagic and that the early larval forms are also pelagic and descend to the bottom-water during the post-larval period. The adults are, as a whole, both shallow-water shore dwellers, and inhabitants of the deeper areas beyond—lurking in the sand or mud where there are abundance of large and small fishes to be lured into the gaping jaws.

The Weever Family. Trachinidæ.

The Lesser Weever. (*Trachinus vipera*, Cuv. and Val.)

For the first account of the pelagic eggs of this species we are indebted to the late Mr George Brook, who, with rare enthusiasm, fitted up tanks of sea-water near his home at Huddersfield, and studied the life-history of this form[1] and that of the rockling. He found that his captive weevers in June deposited their eggs during the night, just as was subsequently found in the spawning-pond at Dunbar in the case of the plaice. They are buoyant eggs having a diameter of 1·25 to 1·37 mm., and containing from 11 to 30 small oil-globules (Raffaele says 4—10). They were subsequently got in considerable abundance by Mr Holt, in Blacksod Bay and other parts off Ireland, in June and July, and are common in St Andrews Bay, at the surface, from May till July. The yolk is clear and transparent and the oil-globules have a greenish-yellow hue (Plate I, fig. 14). The egg-capsule was thought by Mr Brook to consist of two layers, and in section Mr Holt observed that the outer region only took the yellow stain; while the inner was faintly affected by carmine. Practically, however, the egg-capsule agrees with that of other pelagic eggs in structure, as also does the micropylar opening.

Mr Brook gives a minute account of the early stages of development of the egg as they were seen in April, and the late stages as they occurred in July. They hatched in from 9 to 11 days. Dr Raffaele's examples hatched in 8 days in spring, the eggs lying on the bottom during the last three or four days. The spawning-period would seem to range from April to July. Mr Holt found pale yellow pigment, in minute round specks, in the developing embryo, before the appearance of the free tail-region. As development proceeds, the yellow chromatophores become stellate and have a brilliant orange hue. They extend along the upper and lower margins of the tail, and along the gut on either side. Small black chromatophores have also appeared: others by and by occur over the

[1] *Journ. Linn. Soc.* vol. 18, p. 274. Pls. 3—5, 1884.

brain, about the eye and ear-capsules, and on the fins, as well as over the yolk and other parts of the body. Thus, as Mr Holt observes, at a comparatively early stage of development in the egg the yellow pigment is in excess of the black, whereas subsequently it diminishes.

In the recently-hatched larva of Mr Holt, measuring 3·27 mm. (Plate VI, fig. 7) the black pigment of the trunk forms a conspicuous line from the pelvic fins to the posterior fourth of the tail, while, in those hatched by Mr Brook in his aquarium, the pigment was much less developed. Then the black pigment becomes "concentrated into two bars, one above the vent and the other midway between this and the tail, and they remain till the post-larval stage—when all yellow pigment, except three touches at the margin of the dorsal fin, disappears."

Before hatching, the pelvic fins are distinct, and they are soon rotated and carried downward and forward to a ventral position, a little behind the breast-fins. This condition, viz. the early appearance of these fins (pelvic) is remarkable amongst bony fishes. As a rule they do not appear till much later. In three days Mr Holt found that the fishes reached the post-larval stage, by which time the yolk had been absorbed and the mouth and the vent were open.

A fine example (Plate VI, fig. 8) about 15 mm. long (in spirit) was procured by the 'Garland' probably at the end of summer or beginning of autumn—to judge from the condition of a young rockling accompanying it[1]. Many of the adult characters are now present, though the body is much flattened. Black pigment occurs in specks on the snout, a black spot is placed beneath each eye, and each opercular region has the same coloration, which is connected superiorly with that tinting the brain and the snout. Patches of similar pigment are present in front of the breast-fins, and a broad black band extends from the opercular spines rather beyond the middle of the body, and from the dorsum as far down as the lateral line. A few isolated specks exist on the side between the latter and the ventral margin. The lower jaw is directed obliquely upward and

[1] W. C. M. 9th *Ann. Rept. S. F. B.* p. 324, 1891.

forward, and the upper jaw has a well-marked notch in the centre. Five long and strong spines guard the front margin of the gill-cover (pre-operculum) as in *Cottus,* the second from above being the strongest. They are sheathed in skin almost to the tip, and thus from their conical shape are very conspicuous. Two spines, as in *Cottus,* occur on the gill-cover proper (operculum), the upper, long and powerful, directed backward and very slightly downward, and a shorter inferior spine slanting downward and very slightly backward, and therefore at a considerable angle to the former. Two spines project just above the upper angle of the gill-slit. None occurs over the eyes. The breast-fins are elongated, and seem to have undergone a rotation downward, so that the angle formed by the rays with the lateral line, is small. So far as can be observed, the lower agree in structure with the upper rays. The large fan-shaped pelvic (ventral) fins stand boldly out from the prominent median keel, and their bases are distinctly in front of the breast-fins; while they are deeply tinted with black pigment both dorsally and ventrally. The spine is well-developed, but is sheathed in skin to the point. The contour of the belly, as seen from below, differs much from that of the young *Cottus*, since it forms only a small swelling behind the large pelvic fins; whereas in the latter the large tumid abdomen is conspicuous—the pelvic fins forming minute processes at the anterior border. Moreover a somewhat V-shaped mass of black pigment, with the angle directed forward, occurs in the middle line immediately behind the pelvic fins. The first dorsal fin is black, with the first three spines well-developed, but sheathed in skin almost to the tip. It is joined by membrane to the second dorsal, the short spines in this part being still covered. The second dorsal and anal resemble those in the adult. A young Crustacean parasite adheres to the anterior surface of the right breast-fin.

Precisely similar forms about 14 mm. in length were obtained by Mr H. C. Williamson at Naples in May.

In a specimen (in spirit) measuring about 26 mm. (1 inch) the chief changes are in the pigment and the proportionally larger size of the body. The black pigment now has a tendency to form a series of spots along the sides. These form three longitudinal rows in the upper half, viz., a row along or just above the lateral line, another along the base of the dorsal fin and an intermediate more or less double row. Ventrally a row occurs along the base of the fin and scattered specks above it. The two opercular spines are still sharp and prominent, and five long pre-opercular spines are conspicuous, the median being slightly curved as well as longest, and the most anterior being directed forward. At least three spines occur above the opercular slit. The papillæ along the upper edge of the lower lip are distinct.

When 34 mm. (in spirit) the rows of black specks along the sides are distinct, the median being least marked. Only a single opercular (gill-cover) spine, the upper and larger, is present, and the pre-opercular spines are shorter, indeed, on one side only four can be made out. One is directed forward. The breast- and pelvic fins are proportionally larger. The body has increased considerably in depth.

At 36 mm. the three rows of pigment-specks are very distinct, and the scattered ventral series is also present.

At 45 mm. ($1\frac{3}{4}$ inch) in length (July) the aspect from the dorsum is mottled, while laterally the most distinct row of black pigment-spots is above the lateral line. The eyes are more prominent. Only a single spine below the pre-operculum is directed forward; and two point backward. The opercular spine is larger and longer. The other characters are apparently those of the adult. This specimen was procured by digging in the sand while searching for sand-eels. Both species when in the sand escape capture by trawl or ground-net, but both are dislodged by storms, and tossed on the beach. The eyes are proportionally nearer the tip of the snout and look more upwards than in the earlier stages. This approximation of the eyes to the tip of the snout and the protrusion upwards of the whole anterior part of the head are still more marked features in an example 70 mm. ($2\frac{3}{4}$ inches) long. The bands of pigment in this stage approximate more closely to the adult condition.

It is interesting that in the earlier stages *Cottus* and

Trachinus should have so many features in common in regard to the armature of the head and the general shape.

Couch[1] describes a young example of what he considers to be the greater weever, measuring only $\frac{3}{4}$ of an inch in length and captured with a drift-net in August. The opercular spine was not much developed, and the same may be said of those at the anterior superior angles of the orbit. Pigment occurred on the head and anterior portions of the body, diminishing towards the posterior region—which was translucent. "The lower part of the pectoral fins have colour, but the upper portion is devoid of it. Two or three rays on the inner portion of the ventral fins are black."

The Mackerel Family. Scombridæ.

The Mackerel. (*Scomber scombrus*, L.)

The mackerel forms an instance of a fish, whose pelagic habits are not, as in the case of the haddock or the cod, confined to the embryonic and larval stages, but the surface-water in the open seas is the haunt of this species throughout life, with perhaps the exception of its very young stages. This exception is fraught with interest to the investigator, for it might with some reason be conjectured that a fish living in mid-ocean and having a floating egg would thereby be enabled to spend the whole of its life without approaching the proximity of land, in which case it would not be to any great extent available as food for man. Fortunately this is not the case, for the mackerel congregates in vast shoals, and these leaving the open sea migrate towards the land and discharge their eggs in the inshore waters. The periodic migrations of myriads of fishes, as occurs in the case of the mackerel and the herring, are not by any means well understood, but the tendency amongst naturalists is to regard them as migrations connected with the discharge of the sexual function: thus some may be inclined to hold that the mackerel has become secondarily adapted to a pelagic life

[1] Vol. II. p. 46.

and is descended from shore-living forms in the past, and although the adult mackerel is perfectly suited to a pelagic existence, yet the eggs and young stages for their successful development still require the proximity to land, hence the periodic migration of the adults landwards and that of the adolescent forms seawards. The life history of the frog with its familiar aquatic tadpole-stages has usually a similar interpretation put upon it. Granted, however, that the primary cause of the migration of these fishes is due to demands made by the needs of the young there is no doubt that perhaps in a lesser degree, the direction of migration is determined by the sources of food; thus shoals of mackerel are frequently found in keen pursuit of millions of young clupeoids and 'mackerel-midges' (see Rockling). This pursuit of food has been assumed by some to be the primary cause of the migration.

We may approach the question from another point of view. Along with, and contemporaneous with the migration is the crowding together, in a close mass, of myriads of individuals: this massing is directly favourable to the fertilisation of the eggs, it being obvious that the greater the number of fishes that shed their sexual elements in a given area, the greater the probability of fertilisation: on the other hand it is directly unfavourable to the nutrition of each fish, for the supply of food in a given area is limited. Hence the fulfilment of the reproductive function furnishes a factor tending to shoaling whilst that of the nutritive function supplies, on the other hand, a factor tending to keep the individuals apart. If it were not that the latter function is largely suspended in most fishes at the reproductive period shoaling would be almost impossible to the vast extent that occurs in many clupeoids.

The periodic appearance and disappearance of the mackerel, as in the case of the herring, has formed the basis for a good deal of speculation and for the initiation of many curious legends and superstitions. The two most generally prevalent theories in the past may here be mentioned.

It was supposed by many that the Arctic regions were the home of the mackerel (cf. Herring) and that from the Polar seas emanated the shoals to our shores. Lacepéde and others relate on the authority of a French admiral, who apparently derived his information from his seamen, that mackerel could be seen through the clear water on the shores of Greenland with their heads buried in the mud, like the proverbial ostrich: they even went so far as to relate how the fishes, on emergence from their temporary concealment, were partially blind and could be easily caught! Needless to say this story has not been corroborated, and Fabricius and others have been unable to find any mackerel in either Greenland or Iceland.

The other suggestion was that the mackerel retired to deeper water in the winter and passed the colder months in a state of lethargy at the bottom of the sea, a theory peculiarly suitable to the case by its very difficulty of confutation or corroboration. Curiously enough, this point was brought up some years ago in connection with the claim of United States boats to fish in Canadian waters, the right to follow and capture shoals migrating northwards being under dispute.

It is now pretty well ascertained that the middle and eastern parts of the Atlantic form the home of the mackerel which migrate thence into British waters. Towards the end of winter they commence their movements to the coast, and by May and June large shoals of spawning fishes are to be found close inland. Couch states that in these migrations the males precede the females.

Prof. Sars found that the process of spawning is effected quite near the surface of the sea, and he first described the egg as slightly larger than that of the cod, but with a conspicuous oil-globule. It was also described and figured by A. W. Malm of Göteborg. The spawning-season in Norway is in June and July. A mature female may contain about half a million eggs, not an extremely prolific proportion.

The egg of the mackerel has not been definitely described as occurring off the Scotch coast, but Mr Cunningham has followed the early stages at Plymouth, and Mr Holt in specimens from the W. coast of Ireland. The latter states that the egg (Plate I, fig. 16) is 1·22 mm. in diameter with a colourless oil-globule of ·32 to ·33 mm. diameter. Cunningham describes the oil-globule as occupying a position ventral to the posterior of the embryo, but Holt shows that it is really situated at the vegetative pole exactly opposite the middle of the embryo and that it gradually migrates posteriorly as development proceeds. He also remarks upon the 'cloudy' appearance of the globule. The period of hatching extended over six days, with a mean temperature of 14·5° C. (Cunningham).

The yolk is large and elongated and the head of the embryo is closely pressed upon it; there is no trace of a mouth. The pectoral fins may be noticed as small semicircular folds far behind the head. The vent opens a little way behind the yolk-sac. The notochord is multicolumnar. The marginal fins are broad and devoid of all pigment. Yellow pigment is found upon the oil-globule and behind the eyes, black pigment also occurs upon the oil-globule. Stellate black chromatophores cover the dorsal surface of the head and trunk, with a tendency to the formation of a median dorsal row. A few black dots are also seen ventrally. Holt notes that the chromatophores are 'blue-black' and not 'dead-black' as in the rocklings.

The oil-globule, although at first loose in the yolk, early becomes fixed in position by the growth round it of a layer of protoplasm. It may now be seen anterior to the hind end of the embryo. At this stage (5th day) bright green pigment in patches occurs, first behind the eyes and on the tail, near the oil-globule. This pigment and the absence of all yellow colour would at once distinguish the species from any of the gadoids or pleuronectids. Holt described the pigment as of a yellow colour by reflected light, and in a later paper Cunningham explained the 'green' appearance as being due to the admixture of black and yellow chromatophores. This is not a surprising result when we recollect that Holt has noted that the black pigment in this species is of a 'blue-black' tint. The green appearance does not lose diagnostic value on account of its being only an effect and not due to the presence of actual green pigment. By transmitted light Holt found that the yellow pigment appeared to be reddish-brown.

In Plate VII, fig. 1 is shown a lateral view of the newly hatched larva; 3·5—3·9 mm. (Holt), 4·23 mm. (Cunningham).

In four to six days the larva has grown to 4·16 mm.

(Holt). The mouth has appeared and is open. The eyes are intensely black. There is a tendency, in other parts, to lose the black pigment. The oil-globule has now only yellow pigment, and the black pigment on head and trunk is sparse and confined to the median dorsal and ventral regions. A black mass, however, appears on the dorsal wall of the abdominal cavity. The yolk is rapidly disappearing. At the ninth day the larva (Plate VII, fig. 2) has increased to 4·88 mm. in length. The yolk has disappeared and the oil-globule is reduced to very small dimensions. The lower jaw projects and the eyes are, by reflected light, a brilliant blue. The black pigment has increased in the dorsal region of the abdomen but decreased elsewhere. At the 10th or 11th day the post-larval condition is reached, and of the stages beyond this we know nothing.

Holt points out the strong resemblances of the larval mackerel to the larval *Cottus*. He emphasises in his comparison the following characters in common:—the absence of pigment on the marginal fins, yolk-sac, and general surface of the yolk; large stellate black spots on the head and anterior region generally; a mass of black pigment on the roof of the abdominal cavity, and the tendency of the black pigment on the trunk to be arranged longitudinally (not in transverse bars, as in the gadoids generally). If this could be construed into any racial connection between the mackerel and the cottoids, then the latter might be regarded as relations of the former who have not become adapted to a pelagic life but have remained littoral in habit, but this is mere conjecture.

There seems good reason for holding that the embryos in the egg and the larvæ drift landwards in the way described for the cod and haddock and that the post-larval (Plate VII, fig. 2) and young stages are passed in the inshore waters. Dunn states that at Mevagissey the young fishes, about 3 inches long, occur in the bays during August and September, leaving for the deep sea in November when they are from 6 to 7 inches long, and by the time of their reappearance the following June they reach a length of 8 or 9 inches.

Prof. Sars believed that at the end of the first year the young are as long as one's finger, and that in two years they reach the size of a herring, and are 'fully grown' in three years. He states that for the first two years they remain in the open water near shore.

The facts given by these observers can only be reconciled by assuming that the 'young' of about 3 inches described by Dunn must be about one year old, but a difference in length of from 3 inches in September to 6 or 7 in November makes the continuity of the series rather improbable.

Perhaps the series 4 inches—8 inches—11 inches may be taken to express the average rate of growth of the mackerel in the first three years of its life. Sexual maturity appears to be attained at a length of 11—12 inches but individuals have been known to exceed 18 inches in length.

The Scad Family. Carangidæ.

The Horse-Mackerel. (*Caranx trachurus*, Lacép.)

Couch found the scad with ripe roe in the middle of July, Day giving this month as well as June and August as the spawning-season. In the Mediterranean, according to Risso, it is earlier, viz. in spring. Holt found ripe males and almost ripe females on the 16th June at Penzance. The eggs measured ·84 mm. in diameter, with several oil-globules—which, by and by, fused into one. He imagined that they were pelagic, and similar to those of the mackerel except in size. The oil-globule is proportionally large. In September the bays in Cornwall swarm with young, an inch in length, and in October about 2 inches long. Couch also observes that he has found them, not exceeding an inch in length, in the stomach of various fishes, from the end of December to the middle of February; while he has again seen them 3 or 4 inches in length in August and September. Cunningham took similar specimens during the same months. The spawning-period, therefore, as usual, would seem to extend over a considerable time, but chiefly in June and July. The fish is not uncommon, singly or in small numbers in Scotland, but opportunities for the thorough investigation of its eggs and young have hitherto been denied.

Young scads were found by A. W. Malm many years ago in company with the jelly-fishes, *Cyanea* and *Rhizostoma*, feeding on their eggs, and ranging, from the 22nd July to the 18th August, from 12 mm. to 36 mm. They appear to leave the jelly-fishes when 70 mm. in length. They are caught in seines from the latter length up to 100 mm. This habit of frequenting jelly-fishes for shelter and food is likewise found in the cod-tribe, as well as in other forms. The only instance, in which a young fish resembling this form and about 9 mm. in length occurred, was in the Forth on the 25th of October.

A specimen 34 mm. long captured by Mr H. C. Williamson at Naples, on the 8th August, is a shorter and a deeper fish than the adult, with a larger head and eye. The pigment of the body is much less developed than that of the adult, and the two dorsal and the caudal fins are minutely dotted with black. The second dorsal and the anal almost touch the base of the tail. The base of the ventral is behind that of the pectoral of the same side, whereas in the adult they are nearly in the same perpendicular, and the abdomen has considerably lengthened. The lateral line shows indications of the hard plates. This specimen would seem to have been spawned in spring, probably in April or May, and therefore the season is earlier than that mentioned by Day, viz. July.

Boar-Fish. (*Capros aper*, L.)

Risso long ago stated that this species, which is common on the southern coast of Britain, shed its eggs in April, and Mr Dunn found it spawning on the 20th July, 1880. The eggs appear to be pelagic. Mr Cunningham[1] considered that they approached the shore in July and August for the purpose of spawning, and he describes the egg (Plate I, fig. 13) as hyaline, and having a diameter of ·97 to ·98 mm., with an oil-globule ·19 mm. He did not succeed in hatching them, but

[1] *Jour. Mar. Biol. Assoc.* 1889—90, p. 10.

observed that the embryo showed black chromatophores near the dorsal median line.

The Dory Family. Cyttidæ.

The Dory. (*Zeus faber*, L.)

This is a rare fish in northern waters, an occasional specimen only being captured. Couch considered the dory a fertile fish, and "young ones of small size are often met with, but they soon become scattered." Day records that Mr Dunn (Mevagissey) thinks it spawns in winter: and that the young are 2 or 3 inches in length in August. Mr Cunningham[1], on the other hand, is of opinion that spawning takes place about June and July, since in spring the roe was ripening, while in autumn it was "shotten." He gives a table showing that on Oct. 3 the young are 1·7 inches, and apparently, he thinks, about 3 months old. Next June (June 3), they are 4·9 to 5·5 inches and 11 months old. On August 20, 5·3 to 6·1 inches and a year and 1 month old. The following April they reach 9·6 inches with an estimated age of 1 year and 10 months; while in September they are 11·1 inches and 2 years and 2 months. The average size, according to this author, is from 15 to 18 inches, which he says is probably not reached in less than 3 years.

The Goby Family. Gobiidæ.

The Freckled Goby. (*Gobius minutus*, Pall.)

Though of little use to man as food, yet this and other members of the genus are readily preyed on by the cod and other fishes, and from their wide distribution and great numbers they are of greater importance than at first sight appears. The remarkable features of their eggs also claim some attention.

[1] *Jour. Mar. Biol. Assoc.* 1891—92, p. 111.

The eggs of the freckled goby (Plate II, figs. 6, 7 and 8) were figured by Hoffman[1], and indeed had probably long been familiar to marine zoologists. Parnell and Day give the month of June as the spawning-period, but little definite was known of the eggs and larvæ until lately. Those of this species not infrequently occur at St Andrews in May, attached to the inner surface of the valves of *Lutraria* and *Solen*, and they have been carefully figured and described by Mr E. W. L. Holt[2]. Dr Petersen has recently given excellent figures and a description of the eggs of this species, which occurred on the interior of the shells of *Mya arenaria* (Plate II, fig. 8), fastened by the same network as already described. The eggs (Plate II, fig. 7) are somewhat pyriform, though as in the black goby, the outline alters with the developing embryo, and they measure ·9 to 1 mm. in their long diameter.

Mr Holt observes that the egg is elongated—varying from 1·4 mm. to 1·2 mm. The contour is somewhat pyriform, and the narrow end is blunt, almost truncated. The larger end, on which the egg rests, tapers rapidly to a small facet or pedicle of attachment. It will thus be seen that the British examples are larger than the Danish, and differ slightly in outline, being less tapered distally, but a considerable amount of variation probably occurs. The space round the yolk (perivitelline space) is large and is principally in the lower region of the egg. The yolk is bean-shaped, with numerous oil-globules of various sizes. The embryo lies in the long axis of the egg. The capsule is very thin, but has the usual structure.

From the facet or pedicle of attachment, Mr Holt goes on to say, springs a hyaline structure which spreads outward in the form of an umbrella. It is pierced by alternate concentric rows of diamond-shaped or ovoid apertures, which increase in size the further they lie from the pedicle, whilst on the contrary the hyaline intermediate substance is more massive than in the distal rows. Finally the structure is continued in the form of a fringe of long tapering threads, which adhere to the shell and to the threads of the adjacent

[1] *Verhandel. d. Konink. Akad.* 1883.

[2] *Ann. Nat. Hist.* July, 1890, p. 34.

eggs. The latter with this exception are completely isolated. Mr Holt likewise traced the development of this curious process for attachment in the roe of the parent fish, so that there can be no doubt about its identity.

The larval gobies 3 to 3·5 mm. (Plate VII, fig. 3) appear in the bottom-nets towards the end of April and in May, and they are readily distinguished by the air-bladder, and by their coloration. Of a living one of the latter size from St Andrews, Mr Holt[1] observes "the vent is slightly anterior to median, the pectorals are large and fan-shaped, and the embryonic dorsal commences opposite the pectoral girdle. Larval fin-rays occur in the tail. There is a considerable pre-anal fin.... The eye is greenish yellow[2]." Black stellate chromatophores, with yellow amongst them, occur below the anterior end of the notochord, extending as far back as the air-bladder. The latter is greenish, with black dendritic pigment. "Above the vent and between that and the air-bladder are two large masses of gamboge-yellow pigment (reddish-brown by transmitted light), over each of which is a large black stellate chromatophore. Small black chromatophores extend along the ventral edge of the anterior two-thirds of the abdomen and along the ventral edge of the post-anal region to a point a little short of the tail. Midway between the vent and the tail is another yellow patch, overlaid by stellate black pigment, and a similar but smaller dorsal patch lies just above it. The diminished yolk seems to consist almost entirely of small oil-globules."

In those of 5 mm., in the bottom-nets, the yellowish coloration is lost in spirit, but a group of black chromatophores occurs on the occiput and immediately behind, while the post-anal region has four symmetrical black touches—two on the dorsal edge and two at the ventral. A single row of black specks occurs along the middle line of the abdomen. The upward slope of the mandible is marked.

In June they range from 7 mm. to 15 mm., but numerous examples are only from 3 to 3·5 mm. not only in inshore waters, but in the deeper areas, such as the Moray Frith, and generally

[1] *op. cit.* p. 37.

[2] From the dorsum, silvery when viewed laterally.

in the bottom-nets. This variation is in all probability due to the prolonged period during which spawning of the various individuals takes place, and also to the differences in species.

Gobies become common in the nets in July and they vary from 3·5 to 17 mm., and the same may be said of August, when many reach 18 mm.

In September they are likewise abundant in the bottom-nets, and range from 7 to 30 mm., but they do not uniformly increase in size as the month advances, since many towards the end of it are only from 8 to 10 mm. Groups of larger forms from 17 to 25 mm. (1 inch), however, are more common.

In October, gobies of 4·5 to 14 mm. still occur in considerable numbers, both in-shore and off-shore, the average size of the groups being larger than in the earlier months. Towards the end of the month some reach 38 mm. ($1\frac{1}{2}$ in.), and such would appear to be the young of the season.

Again, those of 33 mm. in February, of 33 to 47 mm. in March and of 42 to 50 mm. in April would appear to be the young approaching the end of their first year. In June one specimen may be noticed as reaching $2\frac{3}{4}$ inches. In July the latter reach from 42 ($1\frac{3}{4}$ in.) to 62 mm. ($2\frac{1}{2}$ in.); in September from 62 to 75 mm. (3 in.) or even to 80 mm. Some of the second year however only reach from 55 to 60 mm. in October, so that considerable variety exists. In the following January they attain from 76 to 80 mm. (3 to $3\frac{3}{4}$ in.).

THE BLACK GOBY. (*Gobius niger*, L.)

So little notice was taken of the eggs of this form in Britain, that Day in 1884 does not refer to them, while Parnell observes that they spawn in June. Couch says that he found enlarged roe (ovaries) in February and young ones in autumn. They were incidentally referred to by Mr Saville Kent in the *Handbook to the Fisheries Exhibition* of 1883, and he mentioned that over these eggs the male mounts guard. They were also found by Prof. Prince in the pools near the Beginnish Islands on the West coast of Ireland in 1890. Long before, however, A. W. Malm had referred to and figured the peculiar eggs of these fishes, and so had Hoffman. The southern forms would appear to spawn considerably earlier in the year than those from the north, to judge from the size of the eggs in a female obtained in Guernsey in August. When describing the eggs of the freckled goby in July 1890, Mr Holt referred to the spindle-shaped egg-capsules of the black goby and gave a figure of a preserved specimen. They are not uncommon in the Channel Islands, where the species is frequently met with between tide-marks, and the eggs are fixed in rows to various bodies by the peculiar network so characteristic of the eggs of gobies (Plate II, figs. 11 and 12). An excellent account has been given of the eggs of this and other species of goby by Dr C. G. Petersen[1], the able Director of the Biological Station of the Danish Government. He also refers to the spindle-shaped outline of these eggs, and the narrowing towards the surface of attachment, viz. mussels, stones, ascidians, wood, and sea-weeds. They measure 1·5 mm. long, and have the same loose network of attachment as in the other species; the edge of the network ends in long filaments as formerly described. As soon as these eggs are laid in salt water, the membrane in which they are enveloped bursts, remaining at the lower pole as the network just mentioned. The free end of the egg is able to swing when the water is in motion. The yolk is opaque, lemon-coloured, and has many oil-globules. The larvæ when hatched are 3 mm. long (Plate VII, fig. 4), and show a series of black chromatophores along the central edge of the muscle-plates from the vent to the tail. Only a single spot occurs about the posterior fourth on the dorsal edge. Dr Petersen found that this species was two years in reaching full size, whereas he thought the other species attained their full growth in one year. He is also of opinion that this species is less partial to pure, clear and cool water than the doubly-spotted and freckled gobies. Recently Mr Holt figured a post-larval form of 11 mm. (Plate VII, fig. 5) procured on the West coast of Ireland, on the 11th June, which would show that the spawning-period is similar to that of the other forms. In this the air-bladder is large; the eyes are black with a dark greenish sheen

[1] *Fiskeri-Beretning*, 1891—92. Kjøbenhavn.

superiorly. "The surface of the head and body is covered with a dull olive-green pigmentation, which is only absent from the pectoral and marginal fins, opercular flap and tips of the jaws. The green colour is somewhat darker on the top of the head and abdomen than elsewhere, and dotted with small black chromatophores. Four bands of reddish-brown cross the body at various points, viz. behind the air-bladder, at the vent, at the base of the tail, and between the latter and that at the vent. The body is thus more or less opaque[1]."

THE DOUBLY-SPOTTED GOBY. (*Gobius flavescens*, Fabr.)

The eggs (Plate II, fig. 13) are somewhat similar to those of the freckled goby, and are attached to dead shells of mollusks and cirripedes (sea-acorns), the male, as in the other gobies, keeping guard over them. In the *Scandinavian Fishes* the spawning-season is stated to extend from May to August, and Mr Roberts. who kept them in the Scarborough Museum, found that the eggs hatched on the 16th day. Dr Petersen observed this species spawning in June in the clear and pure water of the enclosed Fjords of Denmark in the grass-wrack region, the eggs being attached to smooth spruce-stakes, to loose grass-wrack, tangles (Plate II, fig. 14) and other structures. Their long diameter is ·8 mm. and where broadest ·6 mm., the British examples being larger. They are also fastened by the characteristic network of the other species. The yolk is opaque, gritty, and slightly brownish, with many reddish-brown oil-globules. He thinks that it deposits its eggs in deeper water than the other two species mentioned, an opinion in agreement with experience in this country.

The early stages of the young of this species have not yet been described with sufficient care to warrant separate consideration at present. Suffice it to say that they occur in swarms in the rock-pools all round our eastern shores in August and September, reaching in the latter month from 20 to 30 mm., while in the following July they attain the length of 47 mm.,

[1] E. W. Holt, *op. cit.* p. 441, Pl. 47, f. 12.

the adult length being, according to Day, about $2\frac{1}{2}$ inches, while the authors of the *Scandinavian Fishes* state that it is from 60 to 65 mm.; they also give a very complete account of the coloration of this species.

NILSSON'S GOBY. (*Crystallogobius Nilssonii*, Düb. and Kor.)

The free eggs of this species have not yet been described, though they are visible enough in the body of the ripe female, in spirit.

The post-larval stages are met with in July. Thus on the 20th July a specimen 7 mm. in length[1] presented a head with a large pair of eyes and a prominent mandible below the open mouth. From the somewhat truncated condition of the premaxillary region, however, the mandible, when closed, is probably bent obliquely upward, and it is also truncated, the margin indeed in each being nearly straight, with a prominence at the outer end, from which one or two sharp teeth project beyond the mucous membrane. The truncated margin is shorter in the premaxillary region, and after an interval there is another prominence with a smaller tooth. From what appears to correspond to the lower margin of the preopercular region, two prominent spines project outward and backward. The branchiæ have simple papillæ. The body tapers gently from the head to the tail, the notochord passing nearly straight out in the latter, though a considerable thickening (hypural) exists beneath. The dorsal marginal fin begins behind the head and joins the caudal. Ventrally it extends from the vent to the caudal. The latter shows only embryonic rays and these are less distinctly marked throughout the marginal fin—dorsally and ventrally. The pectorals are rather large and long, with true rays, the upper and lower being short, the median much longer. They are deeply tinted with black pigment on the inner surface, or what probably is more or less ventral when in motion. It is chiefly developed in the inter-radial integument in the form of isolated squares or patches.

[1] W. C. M. *Ninth Rept. S. F. B.* 1891, p. 322.

Two pigment-specks occur near the middle line in front of the eyes, four symmetrically placed over the mid-brain, with several chromatophores in the middle line behind, the only others being a few at the base of the pectorals ventrally, and along the ventral margin in the posterior third of the body.

Another example, only 4·5 mm. long, in spirit, was got on the 16th of the same month, but it differed very little in structure from the foregoing, for the pectorals had true rays and deep black pigment, the caudal had embryonic rays, and sharp teeth were present.

In all probability these are the post-larval stages of males of *Crystallogobius nilssonii*, which, at that date, had only once been found in Scotland, viz. by Mr Edward, in a rock-pool at Banff. The very early stage at which the special sexual characters occur in this species is interesting, yet Dr Day considered that in the young males the head is more pointed, indeed, almost as in the females—in which the jaws are short, straight, and toothless. It is clear that such a statement requires amendment, especially the supposition that the teeth ('canines') are only developed as maturity is reached. It is possible, however, that the young of both sexes may have male secondary characters. In the small example from St Andrews it was the presence of these characteristic teeth and the shape of the mandible that attracted attention, and yet the larval marginal fin was still present. The description just given may be supplemented by the remark that in the adult male the pectoral fins are remarkable for their "broad (multiradiate) and somewhat lobate form, with their semicircular muscular root, and elongated, roundish shape. When expanded the pectoral fins are as deep as the body." The remarkable coloration of these fins in the post-larval stage is an addition to the series in developing Teleosteans. Since the first specimen was captured Mr Cunningham has procured many adults of both sexes near the Eddystone Lighthouse, while Mr Holt has been equally successful off the West coast of Ireland, and on the East coast of England. It appears to be generally distributed round British shores, though the adults have not yet been secured here. It is sometimes found in as great abundance in Norway as in the South of England. The authors (Fries, Ekström and Sundevall) of the recently published work on *Scandinavian Fishes*, observe that June is approximately the spawning-season of this species, and the development of the post-larval examples would appear to point to May or early June as the probable period on our shores.

In spirit-preparations about 32 mm. long procured in August, and forwarded by the Royal Dublin Society, the black pigment is arranged as follows:—In both sexes, a continuous median line passed from the hyoidean region to the mid-abdomen, while from the vent backward an interrupted series of black chromatophores proceeds to the tail. From the pectorals backward to the vent a series of similar pigment-specks is dotted on the sides of the abdomen. The female in this case was nearly ripe, the ova being visible.

The Dragonet Family. Callionymidæ.

THE DRAGONET OR SKULPIN. (*Callionymus lyra*, L.)

This fish stands in a somewhat isolated position in its relationship to the other food-fishes, and though it is not directly used for food by man, it is utilised indirectly in that it forms an item in the diet of the cod or other food-fishes. Although its development does not closely resemble that of the gobies, there are no good reasons for altering its present alliance with them. Its scientific name is given to it on account of the brilliant colouring of the males. The females besides being smaller are of a sombre brown colour, which is doubtless a protective factor as the fishes haunt the bottom where stones and sand abound. The males are said usually to frequent deeper water though we cannot corroborate this opinion. The eggs are pelagic and fertilisation is effected in the water. So different do the sexes appear that it is not very long since they were described in works on Fishes as separate species. The male dragonet differs from the female, not only in its gorgeous tints but also in other features such as longer dorsal fin-rays, and a larger head. These differences between the sexes, apart from those of the sexual-organs, are known as secondary sexual characters, and such characters as a rule are not found (except disparity of size) in the fishes which lay pelagic eggs. This is probably connected with the fact that the fishes do not pair but merely shed their milt or ova indiscriminately in the water. The dragonet forms an exception in that the egg of this species is pelagic and yet the secondary sexual characters are very marked. In accordance with this, we find that the dragonets instead of congregating in shoals at the breeding season, pair off and move about in couples whilst discharge of the sexual products is effected. The males are said to be rarer than the females, in the proportion of about 1 to 3.

Two theories have been suggested with regard to the origin of sexual coloration. The bright colour of the males is explained as the result of continued selection by the females of the most brilliantly accoutred males, and thus by the law of heredity the brightest males only reproduce their species, and on the other hand, a protective and therefore sombre garb is more necessary to the females than the males in order that the next generation may be preserved. Young males are occasionally found presenting the brown coloration usually characteristic of the females only.

The dragonet appears to spawn from May to August. Eggs are found in most abundance in June, July and August, but some occur in early May (Smith Bank), even at an advanced stage of development[1]. This being the case, the dragonet seems to spawn throughout the summer months, and its breeding-season is long. It is one of the species which occasionally discharges eggs in proximity to the shore, i.e., within the territorial waters.

The egg (Plate I, fig. 15) is comparatively small (average diameter ·025—·03 inch) and perfectly translucent, but is at once distinguished by the fact that outside the egg-membrane are 'a series, for the most part, of hexagonal reticulations like

[1] A. T. M., 11th *Ann. Rep. S. F. B.*

those of a honeycomb[1]. The septa bounding the reticulations stand out very distinctly and their edges show minute striæ.'

The cause and *raison d'être* of these peculiar ridges covering the whole of the exterior of the egg are unknown. They are doubtless part of the egg-membrane thus modified whilst still in the early soft condition. It is curious that in an allied species of dragonet (*C. festivus*) the egg-capsule is smooth, as specimens (·55 to ·57 mm. in diameter) forwarded by Mr H. C. Williamson prove; and this led the able Italian observer Raffaele to conclude that the original description of one of us was erroneous. Cunningham[2], however, showed that such was not the case. This peculiar reticulate capsule is said to occur in *Uranoscopus* and *Saurus lacerta*. The appearance of the capsule of the large egg of the former[3] ("star-gazer") is almost identical with that of the skulpin. A coarsely reticulate appearance is also present in the large thick-shelled egg of *Macrurus* sent from Naples by Mr Williamson. There is no oil-globule. The development of the embryonic dragonet, within the egg, has been observed by Prof. Prince[4] and Mr Holt[5] in the same year, the former in February, the latter in the autumn. Prof. Prince gives the earlier stages, from the second or third day onward, while Mr Holt commences with the larva. The former found that the cortex of the yolk was vesicular or reticulated externally, so that it appeared to be irregularly segmented. Pigment of a rich yellow colour, deeper than canary yellow, and approaching orange, early appears in the embryo. "It occurred as small grains upon the head, before and behind the eyes, and dispersed in this anterior region beyond the embryonic trunk proper over the yolk, but to a very limited extent. A girdle of amorphous yellow spots occurred just in front of Kupffer's vesicle, and others were grouped at the caudal end of the fish. In a more advanced form black pigment-spots had made their appearance." Mr Holt states that the marginal fins are of moderate size, and that the ventral sends forward a narrow

[1] W. C. M. *Ann. Nat. Hist.* 1885, p. 480.

[2] *Jour. Mar. Biol. Assoc.* I (N. S.) pp. 21 and 37.

[3] Kindly sent by Mr H. C. Williamson from Naples.

[4] 9th *Ann. Rep. S. F. B.* p. 349. [5] *op. cit.* p. 442.

strip along the posterior border of the yolk-sac. The notochord is uni-columnar, as in the gobies. The newly-hatched larva (Plate VII, fig. 6) is 2·08 mm. long. The pigment is bright orange, and occurs on the snout; it forms a bar in the middle of the free caudal region, various touches on the marginal fin and scattered points on the yolk-sac. When twelve hours old the yolk has slightly diminished, while the marginal fin has undergone considerable expansion. The body-pigment is now more definite, a dorsal and a ventral touch in the respective marginal fins being opposite the conspicuous bar in the mid-caudal region. Another dorsal touch of yellow occurs in front, and various specks on the head and yolk-sac. When forty-eight hours old[1], the snout is pointed and unusually prominent. The breast-fins form pad-like areas midway between the eyes and the vent, a somewhat interesting position, since in many species they appear much nearer the head. The yellow pigment is still largely confined to the upper half of the trunk, and the sparse black specks are strictly so limited. The dorsal fin is still deeper than in the previous stage. The surface of the larva presented a peculiarly reticulated aspect, which Holt considers to be pathological.

Only rarely is a larval dragonet secured in the nets in May. In June post-larval forms 3·4 to 4 mm. long have been obtained in St Andrews Bay and the Forth, the tail forming a long slender process—feathered with the embryonic rays, and, in the preparations, bent upward. With such a tail, shortening of the body can readily take place, since the thickening at the base (hypural) leads to the absorption of the long larval tail above it. In July, a length of 9 mm. is reached, though some are only 3·5 mm. The mid-water net used in deep water, such as S.E. of the Isle of May, captures just above the bottom many young skulpins from 5 to 12 mm., and they also are found more sparingly in St Andrews Bay. Similar forms occur in the nets in September and October, and since their length has not much increased it is probable that the larger examples have taken to the ground.

A series of post-larval forms of this species, varying from

[1] E. E. Prince, *op. cit.* p. 350.

$\frac{1}{10}$ inch to $\frac{1}{3}$ inch in length have been obtained by the mid-water net in St Andrews Bay during August. Thus they still retain their pelagic habit, but a few are found near the rocks, shewing a tendency to assume the adult habitat.

The smallest ($\frac{1}{10}$ inch) are mainly conspicuous for a large head and trunk and a long whip-like tail. The lower jaw projects at an angle (Plate VII, fig. 7). 'Head and body are speckled with brownish-black pigment-corpuscles, which attain their greatest development on the ventral surface of the abdomen[1].' The predominance of a dark coloration on the under surface is rarely found amongst fishes, this part being usually white or pale, as it is also in the adult dragonet. When the little larva has nearly doubled its length ($\frac{1}{5}$ inch) the head has become flatter, and by a growth outwards of the cheeks, the eyes are carried towards the top of the head, so that they look upwards more than laterally. The upper jaw has grown forwards and the arch of the mandible has increased. The dark pigment on the under side is more prominent than before. At a little over $\frac{1}{4}$ inch in length, the same coloration obtains. The head and trunk are still broad when seen from above. A side view shews the fish to have a fusiform outline. The embryonic continuous median fin has broken up into two dorsals, a tail fin and an anal. The pectoral and ventral fins approach those of the adult in shape, no marked hypertrophy taking place in either pair. There is a spine upon each gill-cover which, at the stage of about $\frac{1}{3}$ inch in length, becomes a formidable armature. By this time also the ventral fins have gained greatly upon the pectorals, being markedly longer.

Shortly afterwards (Plate VII, fig. 8) the adult characters have been mostly assumed. The peculiar protrusible mouth is conspicuous. The paired fins are pale, except for a mass of dark pigment at the fleshy base of the pectorals. The lower surface 'is still coloured with black pigment,' and dark bands extend over the greenish back, one behind the head, and three across the trunk. 'The figure here referred to is from a sketch made some days after confinement in a glass tank in the laboratory, hence the coloration is modified. The

[1] *Researches*, p. 864.

abdominal region is pinkish, from the contained food. The eyes are lustrous and greenish. In the laboratory the young fishes lay at the bottom, keeping the pectoral fins in active motion, while the ventrals were spread out like a pair of wings.' One specimen about $\frac{7}{8}$ in. long, taken from the stomach of a cod, shews the spines on the gill-covers very well developed, and has a close similarity in general features to the adult. The cod is a ground-feeder and this specimen had no doubt taken to the habitat frequented by the adult, namely the sea-bottom in-shore.

This example was obtained at the end of August and it was therefore not more than from 2 to 3 months old, though supposing that it was spawned in early May, there is a margin of nearly four months. The other specimens described, running down in a series to $\frac{1}{10}$ inch in length are all evidently from the same season's eggs, and their diversity in size (though all occur in August) is to be accounted for, to a large extent at any rate, by the fact that the spawning of the dragonet extends over a considerable period.

An example, mentioned in the Trawling Report, $\frac{7}{8}$ in. long, occurred in the stomach of a haddock in October; while others, from 50 to 78 mm., were found in the stomach of the cod, no date unfortunately being mentioned, though in all probability late in autumn. A young dragonet $2\frac{1}{4}$ inches in length, also without date of capture given, shews most of the adult characters. The gill-chambers open by the small opercular apertures situated dorsally, and the opercular spines conspicuously project outwards and backwards on either side of the head. The three spines on each side are mounted on a bony pedicle which protrudes well away from the surface of the gill-cover, the whole forming a powerful weapon of defence. With growth in size the spines become less conspicuous and more closely apposed to the surface of the gill-cover. A specimen of about 78 mm. (3 inches) occurs from the West coast of Ireland in the month of July; this is probably rather less than a year old, belonging to the last of the preceding season's brood. At this stage the transverse bands of dark pigment are still to be made out, especially in the dorsal region, but there is a tendency towards a breaking up of the bands into a number of isolated spots, so that the next stage has the uniform tint of the adult, with dark spots over the body and fins. Another of $5\frac{1}{2}$ inches from St Andrews Bay in November also belongs to the brood of the preceding season but will have entered its second year, as the breeding-season does not appear to continue beyond August. Its age might be from 15 to 20 months, and is probably nearer the latter estimate. Sexual maturity is reached in some females at a length of 6 inches.

The adult seldom exceeds one foot in length, and is usually rather less.

The Sucker Family. Discoboli.

The Lump-sucker. (*Cyclopterus lumpus*, L.)

The eggs of this species (Plate II, fig. 1) are very abundant along the rocky margins from February to the end of May[1] or even somewhat later, one specimen having been procured on the 12th July, 1888. Their colour varies from reddish to straw-tint and even greenish, while in a ripe ovary in the body of the fish it ranges from a beautiful amethystine lustre through the various shades of dull yellow to greenish. They appear to vary in diameter from ·09—·1 inch, with numerous oil-globules, the largest of which are ·041 inch in diameter. When the eggs are partly immersed in a crevice of the rocks and partly exposed, those on the latter surface are straw tinted, while those in the pocket of the rock are of a faint lilac hue. The capsule is dense and minutely punctured, but presents no special thickenings or superficial wrinkles, except where the facets of attachment are situated (Plate II, fig. 2). They are fixed together in considerable masses on the rocks, the water percolating readily through the interstices; but the hatching in confined tanks is somewhat uncertain since decaying débris or the death of a few leads to putrefaction of the whole.

[1] W. C. M. *3rd S. F. B. Report*, p. 60.

In the majority of instances the exposed surface of the masses of eggs presents peculiar and smoothly rounded depressions as if some of the eggs had been scooped out by a predatory fish or mollusk. Such depressions are bowl-shaped, that is, wider at the top or surface, and gently narrowing to the bottom. An attentive examination, however, shows no mark of injury, such as would be caused by the teeth of a fish or by the rasping 'tongue' of a shell-fish. The eggs lie evenly together and their capsules are uninjured. In all probability, therefore, the depressions are due to pressure applied by a blunt surface immediately after deposition; when the mass is soft, it may be by the snout or other part of the male as he fertilises them.

The eggs are chiefly to be found from low-water mark to half-tide mark, often deposited in corners or in holes in rocks. They generally are exposed to the wash of the sea, at St Andrews for instance, chiefly facing the east. In this position they are eagerly eaten by rooks, starlings, and rats. The food-fishes and others are also extremely partial to them[1]. Thus, at the end of April, it occasionally happens that codling caught off the rocks have their stomachs distended with the eggs of the lump-sucker. Even such small fishes as Yarrell's blennies take the same food.

The care which certain male bony fishes take of the eggs is well known, while Dr Günther mentions only two cases in which females do so. In this country the males of the river bull-head, the lump-sucker, and the marine and fresh-water sticklebacks are familiar instances.

Most authors who have treated of *Cyclopterus* have observed this feature in the male; indeed, it is sufficient, under ordinary circumstances, to try to push him off guard with a stick to bring out the feature clearly. Various interpretations, however, have been placed on the habit, some supposing that the mere fact of the male being in the neighbourhood at deposition sufficed to account for its subsequent appearance near the eggs; while others, after Fabricius, bestowed considerable attention on the description of the instinct. In regard to the remarks

[1] W. C. M. *6th S. F. B. Report*, p. 272.

of Fabricius, it is doubtful if the wolf-fish would be much inconvenienced by the attacks of the lump-sucker. Even in its larval condition the young wolf-fish makes an easy prey of the young lump-sucker.

As an example of the paternal solicitude of the lump-sucker for the eggs, the following account may suffice[1]. About the middle of May a male was found at St Andrews, a short distance from low-water mark, in a broad runlet, with his head close to a mass of ova placed on the seaward edge of a stone. The stream of sea-water was so shallow as to leave the stone partly exposed at ebb-tide, and was quite insufficient to float the fish, which was 11½ inches in length. Accordingly, for a considerable period, twice daily, the devoted male had to lie in the runlet on his side, a portion of his body, including the region of the upper gill-cover (in this position), being above water. From the situation of the eggs on the stone just described, the current of the runlet flowed into the mouth of the fish, which, in the warm sun of June, must have been less comfortable than under ordinary circumstances, a fact which is at variance with the 'accidental' theory formerly mentioned. The cool and ever-changing stream, however, sufficed for aeration; the movements of the hyoidean apparatus and the lower jaw, as well as the direction of the stream, causing a current over the upper as well as the lower gills. Thus, although the action of the gill-apparatus and the heart was occasionally a little hurried in the warm sun, no serious effect ensued. For some weeks this faithful male was found at low tide in this position, sometimes on one side, sometimes on the other. In order to test the case still further, Dr Scharff, now of the Museum of Science and Art, Dublin, removed the fish a couple of yards from the eggs and placed it on a stone. It wriggled actively into the water, at once rushed to the eggs, and assumed its former position with the snout almost touching them. The same ensued when it was placed in the runlet at a somewhat greater distance. The solicitude of the males for the eggs which they have under charge was further

[1] *Vide Ann. Nat. Hist.*, Aug. 1886, p. 81, On the Paternal Instincts of *Cyclopterus*, by W. C. M.

illustrated by the occurrence early in May of a heavy sea which swept masses of eggs from their positions all along the rocks. As soon as the sea became calm, numerous anxious males, like 'pilgrims,' were seen by the attendant of the laboratory (who had been familiar with the sites) seeking for their charges. Many of these masses are found on the beach, so that the statement is probable. While on guard the males are frequently attacked by rooks and carrion crows, which thrust their sharp beaks through the abdominal wall, and feast on the liver of the unfortunate fishes, which thus yield their lives to the faithful discharge of their duty.

As soon as the eggs were hatched, the male above referred to was released, and the young scattered themselves in the rock-pools in the neighbourhood in hundreds. It is unlikely, however, that they were dispersed by specially adhering to the body of the male, though they quickly cling to anything and even to each other. Their home for some time appears to be the littoral region, and especially the rock-pools, and they are occasionally found in considerable numbers in August, when the larger examples caught with a hand-net measured about $\frac{7}{8}$ inch. They adhere to the blades of the tangles and other sea-weeds, and in the mazes of these find that safety (by the ready application of their suckers) which would be denied them in the open sea. They are also common in the neighbouring waters inshore, being carried hither and thither on the floating littoral sea-weeds, and thus frequently get into the tow-nets.

In February and March, only ova are obtained. In May the newly-hatched larvæ are about 6 mm. in length or a little longer. They are tadpole-like—with the remains of yolk, the oil-globule occupying the right side, while the marginal fin is continuous, dorsally and ventrally. The caudal has only embryonic rays, and there is a thickening (hypural) beneath the notochord in this region. The short breast-fins show indications of true rays. The circulation in the vessels of the yolk-sac goes on in jerks, so different from the continuously rapid currents in the arteries of the tail and other parts. The dorsal aorta bends downward just within the tip of the notochord. The young lump-suckers swim very actively by rapid vibrations of the tail and the pectorals. The heavy anterior end of the body is thus favourable for progression. The dorsum is pale brownish. The pectorals are pressed closely to the sides when at rest, so that the outline of the fish is that of a short dagger. In Prof. Agassiz's[1] youngest stage the caudal was already partly separated from the dorsal and ventral embryonic fin, and yet the presence of yolk is not mentioned, though the length is only 4 mm. The foregoing, therefore, while larger, was less developed; as, indeed, his figure shows. He fancifully likens the outline to that of the armoured fishes of the Old Red Sandstone, *e.g.* *Coccosteus.* By the 12th day the fish has increased considerably in bulk, and measures 6·75 mm.; and in spirit, besides the disappearance of the yolk and the increase of pigment, the dorsal has now been transformed into two fins (Plate VII, fig. 10), a short crescentic first dorsal, over the vent, having 6 true rays, and a second dorsal, with 11 true rays, joined by a portion of the larval fin (which shows no embryonic rays) to the caudal, the upper region of which (the larval tail) has only embryonic rays to the notch[2], 10 true rays occurring beneath. The anal fin has 10 rays, and is joined to the caudal by a strip of larval fin without rays. In the figure of Professor Alex. Agassiz at this stage (*e.g.* fig. 3, Plate IV), the second dorsal shows 13 rays, the anal 15, and there is no connection between these fins and the caudal. He likens it to the young of *Batrachus.*

Professor A. Agassiz gives some excellent remarks concerning the coloration of these young forms. 'In the youngest stages' (with true rays developing in the tail, or about the 12th or 13th day in Britain), 'the head, in a line drawn nearly vertically below the base of the anterior dorsal, is of a light chocolate brown, with a darker brown band extending from the nostrils above the eye to the base of the anterior dorsal. A light blue band extends from the rear of the eye to the top of the operculum and in front of the eye to the nostrils. A blue spot of similar tint is found at the posterior base of the dorsal and at

[1] *Proceed. Amer. Ac. Arts and Sc.*, vol. xvii., July 1887, p. 286.

[2] The notch is absent in Professor Agassiz's figure (Pl. IV, fig. 1).

the base of the caudal extremity of the posterior dorsal. The rest of the body is straw-coloured.' When the dorsal and anal fins are first outlined from the marginal (Agassiz's, Plate IV, fig. 4), he found them 'usually of a bright olive-green, darkest towards the dorsal side, with the same blue band extending towards the operculum from the rear of the orbit, with one or two round blue spots above the level of the pectorals along the lateral line. Other specimens were of a bluish neutral slate tint, uniformly spotted with darker pigment-cells, with the same blue band between the eyes, above the nostrils, and behind the eyes. This was also the colouring of the oldest of the young specimens caught (from 20 to 34 mm.), resembling in general the bluish colouring of the adult, only of a darker tint.'

'The intermediate stages varied greatly in colouring; some were of a yellowish-brown, spotted with chocolate-coloured patches, with light greenish bands behind the eyes, and five roundish spots of the same colour along the lateral line, and a similar number of larger spots along the base of the posterior dorsal, extending, in some specimens, along the median dorsal line of the body to the coloured band passing between the eyes. Other stages, with a similar arrangement of elliptical spots of a bluish tint along the dorsal and lateral lines, were of a reddish-brown colour, with pigment-patches of a darker greenish or of a brownish colour, the abdominal region being of a lighter colour.'

In regard to the coloration of the British examples (Plate VII, fig. 11) some slight differences from the foregoing careful description of the American forms occur. Thus at 12 mm., in June, the general tint is olive-brown—with an opalescent bluish bar running from the operculum to the eye, and then forward over the upper lip to the mouth where those of opposite sides almost meet. Traces of the same hue occur on the cheeks and on the pectorals. A cross-bar of the same beautiful tint passes between the eyes, so that the whole forms an A, a pale furrow in front being caused by the premaxillary fold. The effect of these bands in many is heightened by a border of russet-brown.

Others a little larger, again, have the body dappled with sinuous brown bands so that it is more or less reticulated, and in addition to the iridescent bluish bands just mentioned have dots on the cheeks, bold touches of the same character along the sides and at the base of the pectorals, the effect being heightened by the orange tint of the inner surface of the anterior rays. At 20 mm. when the lateral spines are developing, the pre-, post- and inter-ocular bands are still present though the last (often greenish) is less distinct. Above 20 mm. the body (as at 25 mm.) becomes more uniformly tinted, such as olive or bluish-green, the ocular belts being indistinct, but at the size just mentioned (25 mm.) the sides of a green example are somewhat silvery, the first dorsal has a brown tip, and the orange tint remains in the pectorals, thus contrasting with the generally pale hue of the ventral surface.

It is interesting that in these small forms slight pressure causes the sucker to adhere in the dead animals.

When 11 mm. long (in spirit), in June, it conforms rather to the 20 mm. stage of Agassiz, since the first dorsal is long, fleshy at the base, and with crenations for rays at the tip. The breast-fins have increased in size, though they do not differ much in their relations to the posterior border of the dorsal, since that has been carried considerably backward by the elongation of the fin. The second dorsal and the anal are prominent, and the caudal has no trace of the larval tail.

Little change ensues up to 17 mm., except the general increase in bulk, the deepening of the first dorsal, and the more evident crenations at the tip. When about 18 mm., however (in spirit), four rows of simple papillæ appear:—(1) A line of minute and somewhat closely arranged papillæ along the dorsal ridge, and extending from the posterior part of the head to the base of the first dorsal. Behind the latter, two rows occur, and they cease before the commencement of the second dorsal. (2) A line of small papillæ extends from the tubular nostril along each ocular ridge, and slopes downward along the dorsolateral region, but ceases opposite the first dorsal. (3) A series of five larger, but still simple papillæ, run from a point above the base of the breast-fin to a vertical line from the vent. (4) A similar number extend along each ventral edge to the commencement of the anal fin. The third line has the best marked papillæ.

At 18 mm. some are variegated with fine touches of silvery white, one or more on each side of the abdomen, and two at the base of the pectoral, the latter inferiorly being reddish brown, as is also the tip of the dorsal. The eyes are silvery with reddish brown round the margin of the pupil.

It is interesting that in the American examples Professor A. Agassiz found no trace of these papillæ in fishes 20 mm. long, yet the anterior part of the body, he observes, had assumed the somewhat angular outline characteristic of the adult, though the body, as a whole, was longer. Indeed, he found the spiny tubercles (of which the foregoing papillæ are the precursors) developed only to a slight extent in young forms measuring 34 mm. The British examples are thus more precocious. Professor Agassiz also describes 'a last row of somewhat smaller tubercles along the median line of the abdomen behind the ventrals.' In all probability 'median' should be 'lateral,' unless the American form specifically differs.

As the fish increases in length, the second and third rows extend posteriorly, and by-and-by become hispid with minute spines; the third, especially, presenting large crescentic eminences bristling with prominent spines, which, while occurring over the tubercle generally, also form a pectinate ridge distally.

In June the young lump-suckers range from less than 10 mm. to 23 mm., the smaller forms being more frequent at the beginning, the larger towards the end of the month. In those of 23 mm. the spiny tubercles are all better marked than at 19 or 20 mm. Thus, the second and third rows (lateral) extend to a line passing through the middle of the second dorsal and the anal. In full development each process in the row forms a multispinous tubercle. A row of small spinous tubercles also occurs at the lower border of the opercular region, one extending to the branchiostegal area. At this stage (23 mm.) the second dorsal has 11, the breast-fins 21, the anal 10, and the caudal 11 rays—these numbers agreeing for the most part with the full number in the adult. On the other hand, the young differs from the latter in the greater proportional size of the eyes; the larger proportional size and the nature of the third row of spines and of the ventral tubercles, in the shape and condition of the first dorsal fin, and in the arrangement of the pigment. At this as well as the previous stage, minute leeches are occasionally found on the skin.

In July, eggs were once obtained in a fully ripe condition (viz. the 12th), but their deposition on the rocks would seem to be rare at this period. Young post-larval forms of only 6·5 mm. are still found at the surface, *e.g.* of St Andrews Bay and the Forth, the majority, however, being between 11 and 30 mm. Many of an intermediate size are obtained in rock-pools. At 30 mm. all the rows of spinous tubercles are extremely prominent, the most conspicuous being four of the third row. This and the second row extend almost to the base of the caudal fin. Such a fish is much more rugose than the adult, whose rows of flattened tubercles contrast with the projecting ridges and their hispid tubercles in the young. The first dorsal fin at this stage has a tendency to be adpressed, so that its tip is guarded by the double row of spinous tubercles on the dorsum. Further, the flattened abdominal surface behind the ventrals shows minute soft papillæ scattered over the surface, the precursors of the hispid processes of the next stage. At this period, therefore, the young lump-sucker is armed at most points, a condition of great importance during its more or less pelagic existence.

At 38 mm. (31st July) the head and body are of a fine bluish green, spotted with isolated black specks, and grained all over with separate black chromatophores. The ventral surface is paler. The pectoral fins have fine brownish-red lines along the rays (one on each side), the lower part of the fin being fawn-coloured. The eyes are remarkably tinted, for a circle of pink surrounds the pupil, while a chrome-yellow ring bounds the eye externally, the whole surface being minutely dotted with black. Thread-worms are common in such forms.

During August the captured specimens (in spirit) range from 13·5 to 35 mm., most being above 20 mm. Large numbers are procured in the salmon stake-nets off rocky borders, the young lump-suckers adhering to sea-weeds which are stranded on the ropes; while some are procured in the ordinary bottom-nets. At 35 mm. the rows of hispid tubercles are more pronounced than in the previous stage. The first five of the third row are very large, the hardened distal region being more or less conical with a pectinate crest of spines which have a slight inclination backwards. Each hardened tubercle moves freely on the softer skin around it. The most evident change, however, which occurs at 31 or 32 mm., is the appearance of minute spinous processes over the skin between the larger rows of tubercles on the upper lateral regions, and on the flattened surface behind the ventral sucker, as well as all over the head, the only area apparently free from them being the abdominal wall between the prominent third row and the lateral ventral series, the tips and spines of which also present a slight inclination backwards. The double row of spinous tubercles behind the dorsal fin have increased in size, making an efficient protection to the tip of the former when adpressed; and probably this is important, since the projecting fin would otherwise be readily seized by a predaceous fish. Three spinose tubercles occur on the lower edge of the opercular region. In contrast with the smooth flattened tubercles of the adult, therefore, the young lump-sucker is remarkably well armed.

On June 1st of the following season one was 62 mm. in length. Others procured in July were 5 inches long (125 mm.), $5\frac{3}{4}$, 6 and $6\frac{1}{2}$ in.; while one in December was $6\frac{1}{2}$ inches long. The latter was covered with *Caligi*, as if in an unhealthy condition.

The Common Sea-Snail. (*Cyclogaster liparis*, Flem.)

Of this form Day observes that Pennant found it full of roe in January. The eggs are small and numerous, if anything of less size than in Montagu's sucker. McCulloch, again, thought that the spawn was deposited near the mouths of rivers, a view, considering their abundance in such estuaries as the Thames, not without probability. In the *Scandinavian Fishes* Ekström found a ripe female 130 mm. long at the beginning of May, the "running roe" being of a light carmine colour, the eggs slightly more than 1 mm. in diameter. Sars met with young specimens up to 15 mm. in length swimming at the surface in July. Unfortunately no ripe example has been procured at St Andrews.

Montagu's Sucker. (*Cyclogaster Montagui*, Donov.)

Couch observes of Montagu's sucker that "its time of spawning is in the spring, and it has been seen greatly distended with spawn in the middle of April, the spawn lying loose in the ovary." Day likewise had only seen nearly ripe adults. The earlier authors appear to have overlooked the eggs of this form, and, indeed, quite recently they have been confounded with those of the herring. At St Andrews they were almost the only eggs obtained by the local trawlers (liners in their fishing boats) in February, March and April, attached to zoophytes—such as *Hydrallmannia* and *Sertularia*, and to red sea-weeds—such as *Delesseria*, besides gooseberry bushes, sticks and other débris. The men worked in comparatively shallow water, viz. from 4 to 6 fathoms. Spawning, however, is not confined to this region, for the eggs are occasionally found near low-water mark, and on the other hand are not unfrequently procured by the liners in deeper water, viz. from 15 to 30 fathoms. During the Trawling Expeditions specimens were sometimes sent as eggs of the herring, from which they are distinguished by the structure of the capsule and of the yolk, and similar forms are in all probability figured attached to zoophytes in the *Second Annual Report of the Fishery Board*, Plates VIII and IX. The spawning-period ranges from January to July, and several examples deposited eggs in the tanks of the laboratory. These measured ·045 inch (and the oil-globule ·0083 inch).

The eggs (Plate II, fig. 10) are smaller than those of the short-spined *Cottus* or than those of the herring (·0615 inch), from which they also differ in regard to the structure of the capsule. The latter presents a minutely areolar appearance (Plate II, fig. 9), due to slight elevations having a more or less linear disposition, the surface somewhat resembling in miniature that of grained morocco leather. In newly-deposited examples or in ripe eggs in the roe, the external configuration shows an almost regular hexagonal character, the sutures being pale, while the central regions are more opaque, probably from increased thickness. After exposure to water a change occurs, the hexagonal facets becoming less marked, while a series of elevations apparently due to a later modification are visible. In oblique views the capsule shows undulating surface-markings. It is at first soft and pliant, hardening subsequently. It is minutely punctured, and the same dense series of layers can be separated as in the wolf-fish and sea-scorpion. The perivitelline space is considerable. In colour the eggs vary from pale-straw or honey-colour to a light pink or flesh-colour, the tint being due to the yolk and its oil-globules. They form little masses which firmly adhere to each other, and to the zoophyte or sea-weed, by a glutinous secretion.

These eggs are very hardy, and even after exposure on the deck of a boat for some hours are readily hatched in the laboratory. In the same way specimens sent a long distance in a little sea-water or damp sea-weed survived the journey.

The newly-hatched larvæ are active, 4·5 mm. in length, and at once swim freely in the water, thus, irrespective of the pigment, differing much from the elongated and somewhat feeble herring. The cuticle presents a finely reticulate appearance on the marginal fin, which everywhere has embryonic rays; and many minute globular vesicles or glands occur on this and the sides of the body. The yolk-sac is studded with stellate black pigment-corpuscles and touches of chrome-yellow, and on each breast-fin is a large spot of yellow with black chromatophores, followed by a narrow yellowish curved band with similar black pigment. A few chromatophores with remarkably elongated processes form a line along the ventral edge of the muscle-plates, but none are found on the dorsal edge. The eyes have a greenish iridescence like a diamond-beetle's wing. The notochord (primitive back-bone) is quite straight to the tip, and its cells are large. The heart has a small oil-globule below it, and the large oil-globule lies immediately behind the heart—in front of the granular yolk. No blood-vessel occurs in the tail proper, the aorta passing almost to the tip of the notochord, and bending upward and forward into the vein. Such larval forms as just described are very common in the nets from March to May, clusters of eggs and ripe females being especially abundant during the former month and April. Post-larval forms, again, of 5·5 to 6·5 mm. (in spirit) occur in April, and in some it would appear as if the body were somewhat shortened in the post-larval condition.

In May also the larval Montagu's suckers are frequent, with various older stages up to 11 mm., the beautiful pigment of the breast-fins being very characteristic (Plate VII, fig. 9). Mr Holt found similar forms during the survey off the west coast of Ireland, the smaller forms being translucent in the fresh condition. In spirit those of 11 mm. have the dorsum and sides minutely dotted with black points, and the breast-fins are finely pigmented. A considerable number of specks also occur on the under surface. In life, however, the fish is translucent, the dots being very minute, only those on the breast-fins attracting notice by the regularity of their arrangement. The dorsal fin shows an anterior differentiation of four rays, as if a first dorsal were indicated, the region immediately succeeding having shorter rays. In this connection it is curious that the adult male American examples have the first six rays prolonged and fleshy. There are 29 rays in all, and the fin is connected with the tail. The larval tail—with its hair-like embryonic rays and the sloping notochord—is still present. The anal fin has 24 rays, and, like the dorsal, is joined to the tail. The pectoral has 30 rays, and the pelvic fins 6 rays, so that in these, as in the other forms, the rays agree with those of the average adult—with a full number of rays. Such forms are met with not only in inshore, but occasionally in offshore waters.

Examples during June are few, but several post-larval forms 6 mm. long have been obtained. These—probably in a sickly condition in the tow-net—form the prey of jelly-fishes like

Sarsia. The young forms reach 21 mm. in July, and the body is now richly pigmented. Spots of a darker hue occur at intervals on the head, dorsal and anal fins, tail and sides. The first part of the dorsal fin, viz. that which was differentiated at 11 mm., is now more or less fleshy, forming an obscure ridge. All traces of the larval tail have disappeared. Those of 90 mm. during this month are probably of the third year.

Small specimens of 6 mm. are occasionally obtained off-shore in August, while the older forms of the season range from 27 to 37 mm., and they practically agree with the adults in external characters. Those of 55 to 80 mm. represent the growth during the second, and perhaps, the latter, even the third year.

In September small post-larval forms of about 4 mm. are still procured in the bottom-net, and older forms of 9·5 mm. in the mid-water net, the larval tail in the latter having disappeared. Thus the degree of development is not necessarily indicated by size, as for instance was shown in an example of 11 mm. captured on the 22nd September in the bottom-net. Though of precisely the same length as that described on the 16th May, the posterior end had no trace of the larval tail as in the latter month. The notch separating the upper region of the tail had disappeared with the larval organ, and the true fin-rays of the tail were symmetrically arranged.

In the first half of October, larval forms rather less than 4 mm. in spirit have been met with, so that, if the diagnosis be correct, the spawning-period is sufficiently prolonged. This is the more probable as unmistakable forms of 8 mm. have been procured at the same time.

One of 45 mm. on the 10th of November probably gives the limit of growth for the season. An interesting table of measurements and calculated ages of various examples is given by Mr J. R. Tosh[1]. The young suckers are eaten by many young food-fishes, the larger being frequently found in the stomach of the cod and other fishes.

[1] 12*th Ann. S.F.B. Report*, p. 335, 1894.

The Lepadogaster Family.

THE BIMACULATED SUCKER. (*Lepadogaster bimaculatus*, Donov.)

This fish is rather more characteristic of the southern and western than the eastern shores, though it is by no means rare on the latter or in the north of Scotland. The eggs are deposited towards the end of June and in July (being most common in July and August), inside empty bivalve shells, such as *Venus*, *Pectunculus*, *Solen*, and *Pecten*, and also along with *L. Decandolii* at Guernsey, in the interior of the hollow basal swellings of the curled tangles, the adult fixing itself beside the eggs by means of the sucker. The eggs (Plate II, fig. 5) are stated by Mr Holt to have a long diameter of 1·37 mm. and a short one of 1·08, while the height is ·68 mm. The preserved eggs have a long diameter of 1·14 to 1·37 mm. and a short one of ·914 to 1·2 mm., while the height is ·64 mm. These dimensions thus agree with those of Mr Holt—taking the contraction caused by spirit into consideration. They are placed separately in most cases, though not with regularity, inside the shells, attached by a flattened surface of a peculiar structure. On the irregular surface of the cavity of the tangle they were somewhat close to each other; indeed, two or three were occasionally lifted together by the basal secretion, and they covered all the available surface. The attached or flattened surface is coated by an adhesive secretion; the micropyle, as Mr Holt in his careful description observes, being in the middle. He found the aperture closed, as was the case also in those examined here, the disks or bosses of the cilia or long papillæ of attachment occurring over it. A fine fibrillar secretion occurs over the whole of the attached surface, the fibres radiating from the micropyle outward towards the marginal fringe. The surface of the capsule (zona) in this region is closely studded all over with distinct pustule-like disks or bosses from which cilia or processes project, the tip being often bifurcate and ending in long filaments. These and the fibrillar secretion just mentioned run into the fringe of fibres at the margin of the egg. In some views the marginal fringe sprang from a series of large basal stems united with the secretion at the margin of the egg. On the other hand, the upper arch of the flattened egg has its capsule so transparent that the ordinary punctures could not be satisfactorily made out in the preserved specimens, though such were formerly considered to be present.

From the observations of Mr Anderson Smith[1], who kept the adults of *L. Decandolii* in confinement till they deposited eggs, which they did all at once, it appears that they hatch on the 28th day. The circulation was noticed on the 13th day. Mr Holt correctly states that the embryos are always horizontal in position; indeed, the shape of the egg would render any other position difficult. In this connection it has also to be remembered that in the later stages the embryos make considerable movements in the eggs.

Mr Holt found different degrees of development in the eggs he examined, and slight variations were also observed in those above-mentioned. The majority, however, in a given case, were nearly alike in this respect. The examination of the ovaries of an example of *Lepadogaster Decandolii* captured in the hollow tangles at Guernsey in July shows that the mature eggs are accompanied by others of various sizes, the largest of which are about half the size of the former. This species may differ in some respects from the bimaculated sucker in regard to spawning. Black pigment is well developed before hatching. A careful description of the larva (Plate VIII, fig. 3), which, on hatching, measures from 2·8 to 2·9 mm., is given by Mr Holt, the only difference in those examined here—but whether *L. bimaculatus* or *L. Decandolii* is an open question—since the females of both species occurred inside this remarkable hatching-chamber—being the presence of scattered black chromatophores over the dorsum of the head. The somewhat regular rows of black specks along the sides of the body are characteristic even at this early period.

The young appear in the bottom-nets as post-larval forms

[1] *Proceed. Roy. Phys. Soc.*, ix., p. 143, pl. vii., 1886.

in August and September, and range from 5 to 5·5 mm. They probably remain, on emergence from the capsule, more or less in the shelter of their original home, until the yolk is absorbed, and sufficient strength is gained for a free existence and the capture of prey. At this stage the larval tail is still present superiorly, with its embryonic rays, while nine true rays occur beneath. Minute black specks appear on the top of the head and under the jaw, with a few on the abdomen, besides the rows along the sides. The prominence of the alimentary canal inferiorly, with the posterior vent, is a feature at this stage. A disc-like thickening occurs on the site of the sucker, but the apparatus is little developed; yet, even this indication of it is comparatively early, since the pelvic fins are generally late in making their appearance.

At 6·5 mm. the larval tail remains as before. The rows of closely arranged black specks go down to the ventral edge, but do not pass to the median ventral region. Two marked pigment-lines occur ventrally on the lower jaw—beneath the eye, and at the opercular region. It is interesting that the young flying-fish (*Exocœtus*) of the Mediterranean is similarly speckled all over, though with less regularity, at the length of 7 mm. At 10 mm., however, the condition of the latter is wholly altered, for it becomes somewhat piebald with rich madder-brown.

At 10 mm. the lateral rows of chromatophores are still more definitely arranged, forming about four complete longitudinal rows on each side, besides minor specks, and the angle of the mandible is more or less horizontal instead of being upturned. The larval tail has almost disappeared, the only trace being the slender tip of the notochord which slants upward to the dorsal edge of the fin, a true fin-ray occurring immediately beneath; but the marginal fin with embryonic rays connects it with the dorsal—in which true rays are developing. Rudimentary true rays also mark the first part of the anal fin. The sucker appears to be nearly complete, but is proportionally smaller than in the adult, probably because the habits are less sedentary. These characters remain at 10·5 mm., except that there are now five short true rays on the proximal side of the slender tip of the notochord in the tail, and the latter is evidently disappearing rapidly. Such stages are met with in September and October.

In December, the young bimaculated suckers reach 15·5 mm., and then occur in the stomachs of food-fishes. Long before this stage all trace of the caudal notochord has disappeared. The tip of the snout is much more flattened, and the eyes proportionally larger and more prominent. The sucker has also proportionally increased in size.

In February the young are from 21 to 22 mm. in length, and more or less resemble the adult, though the tail is large and shows two or three additional rays; that is, about 15 instead of 12. The vent is now nearly median; whereas, in those of 10 mm., it was situated at the commencement of the posterior third. It also presents symmetrical longitudinal rugæ which end in short papillæ around the aperture. The rays in both dorsal and anal fins are 6 (Day gives D. 5–7, A. 4–6). The anterior division of the sucker is minutely papillose, so that its free margin seems to be serrated; and the surface of the median area and two lateral arms is covered for some distance with the same papillæ. The surface of the larger posterior division is also minutely papillose, but the margin has none of the larger papillæ seen in the anterior division. A thin serrate or crenate membrane forms a broad border to the posterior half of its margin, and at this stage, it is, in some at any rate, quite free from the margin of the sucker. A broad diaphanous and striated flap runs forward from it to the base of the pectoral, thus resembling a miniature duplication of the former. The body is now variegated with reddish tints in the males, pale patches occurring along the dorsum. The ventral surface seems to be pale.

At 25 mm. the colours in a young male from St Andrews in June are even more brilliant, the bright red of the eyes and the sides of the body being characteristic. The anterior margin of the first division of the sucker is now flattened out, and the papillæ on the surface are less distinct, while the marginal ones are flattened and more membranous. The accessory flap on the posterior half of the second division is united with the margin of the sucker (a feature, it may be, characteristic of the sex), so that there is no differentiation between them. The vent showed only longitudinal rugæ with the long median papilla posteriorly.

In July, forms of 26 and 32 mm. are obtained, and they seem to be the continuation of the former series. The chief changes are the increase of the fleshy folds of the lips superiorly and inferiorly. The latter form a semicircular flap on each side, with a posterior continuation, the former having the shape of a broad and continuous flap. In the females the distinction between the margin of the posterior division of the sucker and its broad accessory flap is present. The papillæ along the front margin of the anterior division are also distinct in the same sex.

In August, specimens of 22, 25, and 33 mm. from Lochmaddy, North Uist, where this species is the prevalent form, are in the collection. The smallest is thus only the length of that from St Andrews in February, so that either the specimen had grown but little, or had been hatched very late the previous season, unless we are to suppose that very early deposition of ova occurs in the Outer Hebrides. The former is the more probable.

Adults of 53 and 54 mm. for females and 48 mm. for males are met with in the same month, so that they would appear to be at least in their second year. The chief sexual distinctions externally appear to be the greater breadth and more membranous condition of the frilled border in front of the anterior division of the sucker in the male,—thus giving a larger surface. Similarly the broad frill behind the posterior division of the apparatus is increased, and its folds have not the regular and definite pattern seen in the female. Moreover, the frill is indistinctly separated from the sucker proper. The latter, in short, has no free rim, but runs into the frill. The testes of the male are small and compact, like those of the shanny.

On the other hand, the female presents a somewhat thicker rim at the front margin of the anterior division of the suctorial apparatus, and the whole of the horseshoe shaped region is much more papillose, even the folds between two of the rays laterally being studded with papillæ. The semicircle formed by the hind edge of the posterior division of the apparatus stands out freely, and is minutely papillose; while the marginal fringe is composed of symmetrical lobes pointed at the tip, and with two accessory points at each side.

One of the chief sexual distinctions, however, is the great development of the papillæ of the vent in the female. These form long digitate processes inferiorly on each side, the lateral being, in addition, united with the upper so as to form a broad lobose frill. These extend as far as the tip of the median papilla and envelop it. A great contrast, therefore, exists between this species and the females of *Lepadogaster Decandolii*[1]; for the females of this species, at the spawning-season, show only a series of short slender papillæ at the vent, the posterior papilla projecting almost as conspicuously as in the male of *L. bimaculatus.*

After spawning, the ovaries both of *L. Decandolii* and *L. bimaculatus* present a uniform structure, the stroma of the organ in each being filled with what appear to be collapsed eggs with thick walls and a central slit-like region. At first sight they appeared to resemble thick shrunken capsules from which ova had issued, but that they are ova undergoing change is more probable. The appearance differed from that usually seen in Teleostean ovaries, in which a crop of minute ova is almost always found under these conditions.

The Blenny Family. Blenniidæ.

The Wolf-fish. (*Anarrhichas lupus*, L.)

This large fish, also known as the cat-fish, has a very repulsive appearance, in agreement with which are its predaceous habits. Experiments with the living fish show that it can send its teeth about $\frac{1}{5}$th of an inch into pine, and in the trawl the haddocks are sometimes mangled by the aimless snapping of this form. It is, perhaps fancifully, said to enter 'the fishermen's nets for the purpose of plundering them of the entangled fish' (Woodward): but its usual food consists chiefly

[1] The edge of the tail-fin in *L. Decandolii* is regularly and beautifully serrate. Day describes the latter as simply rounded at its extremity.

of echinoderms, crustaceans and mollusks. Its claim to be considered a food-fish can be made good, although its forbidding aspect has no doubt militated against its becoming more popular. Considerable quantities of cat-fishes, after decapitation and flaying, find their way into the market and are known as 'monk.' Numerous authorities who have tasted this fish speak highly of it, and it is interesting to note their various comparisons. Cuvier remarks that 'its flesh resembles that of an eel.' Pennant states that 'the fishermen at Scarborough prefer it to halibut,' and Clarke, another Yorkshire observer, states that the fishermen describe it as 'the best fish that swims': Buckland compares its flesh to a 'veal chop,' Donovan to 'mackerel' and De Kay, (if smoked) to 'salmon.' Lastly, Cuvier states that the Icelanders use its flesh for food, its skin for shagreen, and its gall for soap; and we know that good shoes are made of the skin of the Norwegian species. In spite of all this weighty testimony to the value of the cat-fish, Woodward in 1886 writes—'yet it is a fish which the majority would not receive gratis,' and there is still a great deal of popular prejudice which retards its sale, though many fishermen and their families eat it.

As regards its spawning-period, there is some uncertainty. Woodward makes the statement that—'it deposits its spawn in early summer, amongst the seaweed,'—and Pennant also remarks that its spawning-period extends over May and June. Even in so recent a work as the new edition of the *Scandinavian Fishes* all that is given is "the spawning-season is stated to occur in spring, the time of year when it is oftenest taken." These dates do not appear to agree with conclusions stated elsewhere, and drawn from an examination of the ovaries, which clearly point to a much later spawning-season, probably extending over the months of November, December and January, with a margin on either side. The females are smaller in size than the males and are in a slight minority. One female may produce as many as 40,000 eggs. The eggs (Plate I, fig. 17) are of the demersal type, being deposited in large masses by the female amongst the rocks and weed of the shallow waters. Like most demersal types, they cling firmly together by reason of a secretion extruded from the parent. They only adhere at limited parts of the egg-capsule, so that aeration through the mass is easily effected. Their deposition in large masses doubtless facilitates their fertilization by the male. In size they closely approximate those of the salmon; and indeed until quite recently they were commonly mistaken by fishermen and others for those of the latter fish. Each egg is opaque, of a pale straw-colour with an opalescent hue, roughly spherical and about ·23 inch in diameter (5·5 to 6 mm.). From this it will be seen that it is the largest marine demersal egg with which we are at present acquainted. The capsule is thick, strong and minutely punctured. In each egg is a single large oil-globule with a diameter of about ·068 inch (1·75 mm.). It usually floats in the part of each egg which is uppermost, a common feature of demersal eggs.

The early stages of the embryos inside the eggs are yet undescribed; the eggs received at the St Andrews Marine Laboratory in the second week of January, 1886[1], containing already well-advanced embryos with silvery eyes, and pigment in the anterior dorsal region. There were also a number of prominent blood-vessels in connection with the yolk, to facilitate its absorption; a feature absent in most pelagic embryos. The larvæ (Plate VIII, fig. 1), hatched about a week later, were as much as ·47 inch (12 mms.) in length. The body at this stage is translucent and slender. The yolk is straw-coloured with a dull oil-globule situated at the anterior extremity of the yolk-sac, a unique position, so far as known, amongst British forms, though one or two Mediterranean species have an oil-globule anterior in position; and so with the *Coris*-like form of Mr Holt. The larvæ rest mostly back upwards, the body of the fish appearing like a long appendage of the large quiescent spherical mass of yolk, which raises the former well above the sea-floor.

This larva, the largest British marine Teleostean larva yet described, has been compared and contrasted with that of the largest British freshwater fish, namely the salmon[2].

[1] McIntosh and Prince, p. 874.

[2] *Op. cit.*

An epitome of the main differences is here given:

Larva of Wolf-fish.	*Larva of Salmon.*
1. Yolk and contained oil-globule of inconspicuous colour, and yolk-sac spheroidal.	Yolk of reddish orange colour, from contained oil-globules, and elongated in outline.
2. Single large oil-globule anterior in position.	Many small oil-globules situated in upper part of yolk-sac.
3. Snout very blunt, so that the eyes are the most anterior part of the head.	Snout protrudes well in front of the eyes.
4. Marginal fin continuous.	Marginal fin with interrupted outline, forming separate median fins.

These leading features will at once serve to separate the two species at the larval stage.

The blood-vessels in the yolk-sac are, as already indicated, remarkably developed; and a minute account of the changes undergone by them during later development will be found elsewhere[1]. A comparison of these and other organs in the wolf-fish and the salmon show that the stages presented by the former after hatching are passed through by the latter in the egg, so that the young salmon hatches at a stage more resembling the adult, in this respect being further removed from the type of development presented by the pelagic larvæ of the gadoids and pleuronectids. We may here state that the fact that the young salmon only hatches at a comparatively late stage of development, compared with marine Teleosteans, is in accordance with the generalisation that all animals having a fresh water habitat tend to acquire a much modified and protected form of development. This is no doubt a direct adaptation to their more precarious surroundings: the numerous vicissitudes and dangers of our streams and rivers, compared with the sea as a nursery, are obvious.

The absorption of the yolk is slow, and the larval period may thus continue till the end of June, but may terminate in some cases at the middle of May.

Upon hatching, the larva is of a dull yellow translucent colour, with a few black stellate pigment-spots upon the head,

[1] *Op. cit.*

behind the pectoral fins, in the dorsal wall of the abdominal cavity, and a few over the upper part of the yolk-sac. The pigment rapidly increases to form a blackish band on each side from the pectoral fin to the vent. 'In lateral view, it becomes aggregated largely in two lines, and gradually reaches the base of the tail.' The pectoral fins are well developed, and are kept in active movement. They gradually increase in size and become large fan-like expansions. The ventrals arise late. The median embryonic fin is, as above mentioned, continuous from the back of the head to the vent, and forwards to the yolk-sac. It rapidly diminishes in size in comparison with the growing body. In a fortnight it is broken up into separate fins, and spinous rays appear at the second month. The tail is usually more or less lobulated, though it may be lanceolate; thus the shape differs from that of the adult tail-fin.

At the expiration of two months the larval fish has increased considerably in size; the fin-rays, dorsal and ventral, are the same in number as in the adult, and the pigmentation has become more pronounced. The head, closely covered with pigment-spots, presents a slate-grey hue, the same tint being continued on the anterior part of the body. Double longitudinal lines of black pigment run dorsally and laterally throughout the trunk, and, later, black spots extend to the ventral marginal fin.

Plate VIII, fig. 2, shows a lateral view of the young fish at the end of about three-and-a-half months. The sides have a silvery lustre with oblique black markings, especially conspicuous in the abdominal region, and extending a short way over the yolk-sac. The back and sides present a greyish black tint with black specks. The eye is silvery. The jaws are well-developed and the snout has grown forward between the eyes.

At a length of five to six inches (in July) the young fish shows an interrupted row of black spots on the dorsal fin: similar black spots on the sides may coalesce more or less to form bars. This forms a transition to the adult condition with its bold stripes on the back and sides, and reminds one of the condition of the spotted sea-cat of Norwegian waters. Such specimens are probably about 6 months old, perhaps more, though we cannot speak confidently on this subject. This size is succeeded by specimens $7\frac{3}{8}$ inches, in August, and towards the end of the same month by a third, $8\frac{1}{4}$ inches in length. We may here note that the wolf-fish passes from a uniformly tinted larval form to the barred adult, in direct contrast to the salmon which has a barred larval 'parr'-stage, and yet is uniformly tinted in the adult.

In March, again, others measure $8\frac{1}{2}$ inches to $9\frac{1}{2}$ inches; in May 11 inches.

As regards the habits of this fish, little is known. The early stages are no doubt passed amongst the rocks and weeds of the sea-floor. Development appears to be more rapid at sea than in tanks, for the smallest trawled specimen (17 mm.) on the 21st of January had already absorbed its yolk, whereas some in the tanks as long as 23 mm. were still encumbered with this element. The larval forms are apparently more pelagic than the adults, which live for the most part on the ground. The adult fish is usually regarded as more or less of a deep-sea form, and is frequently taken on the haddock-lines: yet it is common on the rocky bottom inshore, as near Crail. Edward states that they are frequently thrown upon the shore after a storm in the Banff district, which points to a habit not always confined to the deep water.

In regard to the rate of growth, the newly-hatched larva is very large, about $\frac{1}{2}$ an inch (12 mm.), and the adult may attain a length of about five feet. In six or seven months, viz. in July, its length may be 6 inches, and the following February it reaches from $8\frac{1}{2}$ to 10 inches. In its second year it may grow to a length of 18 or 20 inches.

BUTTERFLY BLENNY. (*Blennius ocellaris*, L.)

The eggs of this southern blenny were apparently those found by Mr Cunningham attached to a hollow bone brought up by a hook in deep-sea fishing off Cornwall. As the adult accompanied the eggs the probability as to the identity is greater. They had an orange-red colour and a transverse diameter of 1·2 mm. The colour was due to the yolk, which consisted of separate yolk-spherules, and a number of oil-globules occurred near the tail of the transparent embryo. The black chromatophores were confined to the dorsal portion of the yolk-sac.

Yarrell's Blenny. (*Chirolophis galerita*, L.)

Nothing is said about the breeding of this fish in Day's *British Fishes*.

In the *Researches*[1] it is stated that a fine male caught about the middle of June presented only partially developed milt; whilst a female in August had minute eggs in the atrophied ovaries. In a female captured in September the ovaries were large, the individual ova, which were about equal in size, measuring $\frac{1}{18}$ inch.

Two females sent from St Andrews in July, 1861, had both ovaries greatly enlarged, so as to change the outline of the fish. There is, however, an element of uncertainty, after so long an interval, as to whether the date referred to the receipt or the capture of the examples. In any case the remarkable uniformity of these large eggs would lend countenance to the view that this fish has demersal eggs. The eggs, in spirit, ranged from 1·7 to 1·905 mm., so that they are comparatively large for so small a fish.

The Shanny. (*Blennius pholis*, L.)

Common as this fish is its eggs have not hitherto received satisfactory attention, probably because they have been difficult to procure, or have not been searched for with sufficient perseverance. Parnell in 1837 mentioned correctly that it spawns in June. R. Q. Couch also found that summer was the spawning-season, and gives an interesting account of the occurrence of the spawn in rocky crevices or chambers near low water, the roof of these being more or less unbroken, so that the eggs may be laid close together on the roof and sides. Their colour is a

[1] *Op. cit.* p. 677.

bright amber, and they are about $\frac{1}{10}$ of an inch in size. The minute cavern, indeed, looks as if vaulted with mosaic work. He found the female several times in the cavern—in the act of spawning. Day alluded to the foregoing and adds that Mr Dunn thought they spawned in spring. Mr Saville Kent, again, watched them breeding in the Manchester Aquarium, the male mounting guard over the eggs.

In May a large male, $6\frac{3}{4}$ inches long, was procured at the East Rocks, St Andrews. The testes were highly developed, and almost reptilian or amphibian in appearance. They form two large flattened organs, or rather are rounded anteriorly, and flattened on the inner side—the two bodies, in fact, being precisely like the two separated halves of a long bean The blood-vessels run along the flat surface, and give off branches which form as it were a midrib. In colour they are of a faint pinkish white. The outer or convex region is of a firmer texture and more translucent than other parts of the testis, being composed apparently of tubules containing spermatozoa in full activity and abundant sperm-cells. The whiter opaque region consists of aggregated sperm-sacs. The spermatic duct leading to the genital aperture is exceedingly wide, and on one side shows a spermathecal enlargement, distended like an additional urinary bladder when the fish was opened. The ducts debouch by an aperture on a prominent papilla behind the large corrugated anal orifice. This strong papilliform protuberance resembles that in fishes which are known to copulate, but there is no record of such in this species. A little later (viz., on the 23rd June) an adult female, 5 inches long, had the ovaries much enlarged—containing a mass of large bluish-grey eggs, and smaller eggs of a slightly orange hue. The larger eggs, which were not quite mature, measured about ·0415 of an inch in diameter. The minute structure of these somewhat peculiar ova has been carefully described by Dr Scharff[1]. He especially pointed out that in the ovary or roe the sheath or follicle enclosing the developing egg is peculiarly modified so as to form a thickened cushion over one half of the egg.

[1] *Proc. Roy. Soc.*, 1886, and *Q. J. Mic. Sc.* Aug. 1887.

Very young examples of the shanny are still desiderata.

Older stages are caught abundantly in the rock-pools in August and September and range from 17 to 25 mm. in the latter month. At 23 mm. (on the 24th August) the little fish is studded all over with black pigment on a greenish grey ground. Larger chromatophores occur along each side of the dorsal fin, and a few on the mid-lateral line, and along the ventral edge. Symmetrical areas of minute specks appear on the sides of the jaw and near the tip on the under surface, otherwise the abdomen is pale ventrally. The pigment on the sides has a tendency to be grouped in bars as in the wolf-fish, a condition also partially apparent at 17 mm. Four of these are very distinct. A few isolated glandular pits over the pectoral fin indicate the lateral line.

In regard to the outline of the dorsal fins the shanny at this stage rather resembles Yarrell's blenny than the adult, since the division between the anterior and posterior is marked by a deep and broad V, and the dorsal margin is boldly arched. The first region has many minute pigment-specks on the rays, and anteriorly a few on the fin-membrane. The posterior division has only a few specks on the anterior rays. The first part of the dorsal[1] has 12 rays; the second 19. The breast-fins are very large fan-shaped organs and three of the anterior rays have thickened terminations. There are 13 rays in all. At 17 mm. the pectoral fins are still larger, being about a third the total length of the fish, and remarkably speckled with black pigment, chiefly on the interradial membrane. The pigment disappears before the fish reaches 25 mm. The pelvic fins have two long and powerful rays curved outwards and upwards and forming efficient organs for aiding progression on land, while a third ray occurs behind the second, but whether it is a process of the former or a distinct ray was not made out. These fins at 17 mm. show three rays and traces of a fourth at the outer border. They are also slightly speckled with pigment. In the south, as at Naples, this length is reached in June, the speckled pectorals and the dorsal bars of pigment being well-marked. The anal has 21 rays, the first two being smaller

[1] This is a term of convenience, as the fin-membrane is continuous.

than the others. The caudal has 19 or 20 rays, 13 of which are long. Day gives the following as the fin-formula of the adult:—D. (1) 11—12, (2) 18—20; P. 13; V. 2; A. 18—20; C. 13. The margin of the anal fin is even, so that its entire length would be useful in progression. It is thus in marked contrast to the high arch of the dorsal fin. The surface in front of the vent is deeply grooved and the margin papillose, the genital papilla occurring posteriorly. The teeth are sharp and well-developed. A flap with a bifid extremity overhangs the lower nasal opening.

Those captured in September (22nd) ranged from 20 to 32 mm. In the former case the breast-fins are beautifully speckled with black pigment, and a little also occurs on the ventrals. The dorsal fins are very minutely dotted with the same colour, those on the rays being most visible. In this, as in the longer forms in August, the high arch of the dorsal fins was marked. In both, all traces of the larval tail had disappeared. A short third ray in the ventral fins is quite evident behind the second, and the process over the lower nasal opening is present. The curve of the lateral line is distinct above the breast-fin.

That at 31 mm. shows a decided increase in the pigment all over the fins, and traces of six bars are seen dorsally. The third ray of the ventrals is still visible, and the great size of the two rays is characteristic, though it is true all the fins have strong rays. The two short rays at the commencement of the anal are likewise distinct. The bifid flap over the lower nostril is very prominent. The lateral line ceases a little behind the tip of the pectoral.

The variation in regard to spawning is indicated by two specimens captured in a rock-pool on the 7th October, and which are 19 and 26 mm. respectively. The large black chromatophores on the breast-fins of that at 19 mm. are striking, and resemble those on breast-fins of the young long-spined bull-head; whereas at a later stage they are less evident. Parasitic *Caligi* occur on these forms.

On January 24th a specimen of 32 mm. was obtained, and it showed chiefly adult characters, though the gap in the dorsal fin was still large, and the dorsal edge of both divisions highly arched. These fins were much more pigmented than in the younger stages, whereas the breast-fins in the preparation are pale. Moreover the tips of five of the anterior rays are considerably thickened—probably in connection with their functions in progression and sensation. The ventral fins are even stronger than formerly. The two short rays remain in front of the anal. The flap over the lower nasal opening is shorter and seems to be simple.

In August of the year following, the young shanny attains a length of 66 mm. (Guernsey) to 85 mm. (St Andrews). As they increase in size the teeth become blunt.

The Gunnel. (*Pholis gunnellus*, L.)

Like the viviparous blenny, the gunnel[1] is characterised by the presence of an unpaired reproductive mass in the form of a median band between the intestine and the roof of the abdomen. Unlike the former, however, the milt of the gunnel is also single. In Day's *British Fishes* all that is mentioned in regard to the spawning of this form is—"Nilsson states that its spawn is deposited in November. Mr Peach, however, in June believed he discovered the spawn of this fish at Fowey, in Cornwall." Frequent examination of the reproductive organs showed that the latter observation was incorrect. In May the milt is less prominent than the roe, the latter being the larger organ. The milt, indeed, appears to be in a state of degeneration, large fatty globules and other granules taking the place of the sexual elements. The eggs at this time show great variation in size. Towards the end of November the females, though of small size, present a large, clavate ovary or roe, tapering from the liver in front to a point behind the vent. The eggs are now readily seen by the naked eye, those on the surface being of nearly uniform size, viz. about ·043 in. in diameter. Several oil-globules (·012 in. diameter) occur in the larger eggs, and the yolk is opaque—on account of the abundant straw-coloured, almost

[1] McIntosh and Prince, *op. cit.* p. 676.

opaline, yolk-spherules. Outside the roe is a transparent membrane, not readily removed from the surface.

In the recent work on *Scandinavian Fishes*[1] the authors had overlooked previous remarks on the subject, so that they only observe that "the ovaries of the female are full, and the milt-sacs of the male distended at the end of October," thus showing that the spawning-season occurs in that month, or soon after. As Malm, however, found one of 31·5 mm. in July, and others are recorded by Kröyer, the spawning-season, Malm thinks, must be later.

The free eggs of the gunnel were first noticed by Mr Anderson Smith, and they adhere to each other like those of the herring or sea-scorpion.

They were next observed at St Andrews between tide-marks in masses about the size of a Brazil-nut in holes of the boring shell-fish, *Pholas*, at the Pier rocks, and almost every season they have been found between December and March in similar positions. Moreover, several examples have deposited their eggs in the tanks of the Laboratory, so that Mr Holt was enabled to draw up an account of the oviposition and early stages. When observed in the holes of *Pholas* the parent-fishes were coiled beside the eggs, and the same happened when they spawned in the tanks of the laboratory. Those in Shetland seem to be somewhat later in spawning, since eggs at the hatching point occurred in April. Mr Holt found that on the 10th February one had spawned and that the female was engaged rolling up the mass of fertilized eggs into a ball (Plate VIII, fig. 6). The body was so curved that the head rested on the tail, the mass of eggs being held in the loop thus formed. Occasionally the body was constricted so tightly that the eggs slid over the back, again to be encircled. Sometimes the male, which is the smaller, alternately encircled the eggs with the female. "The object is evidently to prevent the ova, which are adhesive only when first extruded, from being scattered and lost, and it may be supposed that the operation is performed before the eggs are deposited in the narrow crevices in which they have been found." This care of the eggs

[1] Fries, Ekström and Sundevall, 2nd edit. (Smitt), 1893, p. 223.

taken by both parents is not common amongst fishes, since in cases where any attention is paid to them it is the males which do so, as in the sea-horses, sticklebacks, lumpsuckers, *Arius* and others.

The egg has a diameter of 1·71 mm. (·076 in. McIntosh and Prince), with a colourless yolk, and a single oil-globule about ·51 mm. (·0166 to ·016 in. McIntosh and Prince) in diameter, with a granular area beneath it (Plate II, fig. 4). The capsule is thin and fragile, so that it is impossible to detach a single egg from the rest without rupture. Mr Holt found that the egg reached the eight-cell stage at the end of the first day. At the end of the second day there were sixteen cells or generally a mulberry-stage, with the yolk drawn into an apical prominence within the growing disc. Steady progress was made day by day—so that on the seventh day the germinal cavity had formed, and on the 11th the blastopore had closed. On the 12th day the rudimentary eyes appeared, on the 14th traces of the heart, and on the 21st the rudimentary ears, while a slit was visible in the gut on the 25th day. No pigment was yet present.

The hatching period is considerably over a month, probably about six weeks, after fertilization.

The larva (Plate VIII, fig. 5) measures just over $\frac{1}{5}$ of an inch ($\frac{11}{50}$), and is extremely translucent, the only dark region being the pupil. The snout is blunt and the head large, with very large ear-capsules. The most remarkable features are the extreme length and thinness of the young fish, its eel-like form, the great length of the gut, and the character of the yolk-sac, which is directed somewhat forward. The latter is not of great size, and the yolk-proper is of an elongate ellipsoidal shape with a faint opacity, and having in its lower anterior part a single oil-globule of crystalline translucency, very slightly tinged with ochre, and surrounded by a coat of protoplasm. The liver entirely covers the posterior surface of the yolk—projecting as a long cellular organ from the abdominal cavity—and insinuating itself between the hypoblastic covering of the yolk and the thin yolk-sac. The gall-bladder occupies the upper and posterior portion of the liver—just at the angle where the ventral embryonic fin joins the yolk-sac. De Filippi had formerly shown that in the twaite-shad the gall-bladder lay behind the yolk, but the liver in this instance did not pass downward. The breast-fin is somewhat fan-shaped, very thin (membranous), and stands erect. The other structural features are of great interest, and have been already published by one of us in conjunction with Prof. Prince[1]. The mouth is open, but only tremors of the lower jaw are noticeable, aeration being much aided by the exposed condition of the gills. The eyes have a silvery lustre with a black pupil. A few black pigment-corpuscles occur over the upper curve of the eye anteriorly, and this region shows a fine green shade like malachite.

In a fortnight, finely branched black pigment is seen over the corrugated gut posteriorly, and smaller specks as far forward as the yolk-sac, and backward along the edge of the muscle-plates. A few also appear over the yolk-sac. The larvæ exhibited a tendency to lie on their sides at the bottom of the vessel, a feature, indeed, they showed after the lapse of five weeks.

At the latter date a well-marked ventral line of pigment runs from the heart to the vent, passes forward and upward behind it, and is then continued to the tail. This pigment anteriorly ceases before reaching a line from the breast-fins, an oblique bar on each side, forming a ʌ with the apex directed forward, occurring in this region, only a short streak of pigment existing in the middle line in front. No trace of ventral fins is apparent. The body is surrounded by a marginal fin—dorsally deepening a little in front of the tail, which in outline is somewhat lobate. Embryonic fin-rays are present in the tail and in the breast-fins. The snout extends about half the diameter of the eye in front of it, and the lower jaw projects a little further, but is motionless, aeration of the gills being accomplished, as in many other larval fishes, by their active progress through the water. The large size of the ear-capsules, which nearly meet in the median line dorsally, is an interesting

[1] *Op. cit.* p. 868.

feature, while the brilliant green hue of the eyes from above renders them conspicuous.

In the bay, the post-larval gunnels appear in the various nets from the middle to the end of March—varying, in spirit, from 11 mm. upwards. The black pigment corresponds in arrangement with that already noted for the larva, except that a few chromatophores occur at the sides of the vent, and opposite the breast-fins. Fine (embryonic) rays exist in the tail, and an opacity in the lower part of it—due to the development of true rays. These fine rays have also spread to the median fins. The free post-larval forms reach 14 mm. on the 28th March, and they are stronger and better developed, though the posterior gills are more or less exposed. On the other hand those in confinement were still carrying the yolk-sac at this date, and were slender fishes of 13·5 mm., with the fin-rays less advanced. At the end of March some free examples had reached 17—22 mm., and in the middle of April true rays and the basal (hypural) elements had developed in the tail. A marked contrast was thus exhibited between the rather emaciated forms in the laboratory and those in the midst of abundant food and pure water in the sea.

Rapid growth in length and depth takes place in May, when they are found abundantly amidst the myriads of young sand-eels which crowd the tow-nets about fifteen miles offshore, and are procured in smaller numbers inshore, measuring at this stage from 20 to 32 mm. At 20 mm. a slight line of black pigment occurs on each side of the abdomen, and the basal region of the tail-fin is asymmetrical from the projection of the tip of the axial rod (notochord). In those of 30 mm. this asymmetry has disappeared, and minute ventral fins are now visible. One of 35·5 mm., procured in the bottom trawl-like tow-net in St Andrews Bay[1], presents a remarkably transparent appearance, the only colour being the pinkish hue of the gut from the contained crustaceans. The eye is much less in proportion to the size of the head and the latter occupies much less bulk in proportion to the body. Nevertheless the eye seemed to be large and prominent in life when viewed from

[1] McIntosh, *Ann. Nat. Hist.* August, 1890, p. 183.

above. It then has an iridescent greenish-bronze appearance. Ventrally a black pigment-line begins on the hyoid and continues along the median line to the vent—just as in the younger form, except that in front it now passes between the separated limbs of the ʌ-shaped arrangement. A line of the same chromatophores proceeds backward from the vent to the tail. In addition to the foregoing a band of small though distinct black pigment-spots commences on the lateral region behind the breast-fin, and extends to the vent. A single spot occurs on each side beneath the breast-fin, and thus below the foregoing. During life all these pigment-specks were in a state of contraction; but as death approached they gradually assumed a stellate form, and thus the spirit-preparation shows the coloration much more distinctly than the living animal.

The breast-fins are proportionally large. All the dorsal interspinous bones, as also the articulation of the fin-rays, are evident, whereas only the first three or four of the anal are seen, the first, indeed, alone presenting an articulation with the fin-ray. Thirty-seven inferior (hæmal) spines occurred in front of the vent. A few minute black pigment-specks are visible (under the microscope) along the spinal cord. The rudimentary vertebral axis (notochord) remains for the most part simple. The basal elements (hypural and epiural) in the tail bore the following rays:—eight on the large inferior one, three on the next above, then one or more intermediate, three to the upper, above which lay the tip of the notochord, while four rested on the superior elements (epiurals). The total number was thus nineteen as contrasted with fifteen—given by Day as the number of rays in the adult. The dorsal fin-rays were 79 or 80; Day gives 75 to 82. The anal fin had 44 rays; Day mentions 39 to 45. Only eleven rays were distinguishable in the breast-fins; Day states that the number is 11 or 12. As the fish was quite translucent these numbers are of interest. Both dorsally and ventrally a portion of the larval fin existed in front of the tail. The whole fish is active and muscular, and its transparency fits it for joining with others—both round and flat—in that wonderful pelagic life, so different from that of its parents in the rock-pools and runlets along the shore.

A difference in regard to the assumption of the characteristic pigment of the adult stage seems to exist, as indeed might be expected. Thus some of 28 mm. from the West Coast have this fairly developed, while others considerably larger, in spirit, are devoid of such.

Young gunnels of 28 mm., resembling the adults, were captured off the Island of May in the mid-water net at 30 fathoms, but probably the net touched the bottom. They are thicker and more massive than the former, and the region from the base of the breast-fin to the tip of the snout is longer. The ventral fins are well-formed. The pigment along the sides forms a series of reticulations with the long diameter of the ovoid pale spaces vertical. These were considered by Malm as the precursors of the lateral spots of the adult. In those of 40 mm. observed here, the pale spots were dotted all over the sides of the body. Eleven black bars are continued from the body to the dorsal fin without a trace of the eye-like areas of the adult. Similar though less distinct touches inferiorly proceed on the anal fin, which Malm stated in the Swedish example was edged with flame-yellow and marked with the indistinct, whitish spots, set in oblique rows. He also found the tail had a flame-yellow tip. Indications of the line of pigment observed in the earlier stage a little above the ventral border of the abdomen are still present, but all the reticulations just described have been developed subsequently and independently. The median ventral pigment-line is also quite distinct—from the hyoidean region to the vent. The modification of the numerous and somewhat small lateral reticulations into the larger vertical bars of the adult is easily followed in a series of specimens, as also the gradual diminution of the pectorals. A characteristic feature in this young stage is the presence of a K-shaped arrangement of black pigment on each side of the head, the strong bar of the K uniting with its fellow above the brain and proceeding forward over the eye to the tip of the snout. One leg of the K goes from the eye straight downward to the edge of the mandible, while the other slopes backward to the opercular region.

The earlier form (35·5 mm. on the 23rd May) and that last-mentioned represent further stages of the season's growth. On 22nd July, S.E. of the Isle of May in 30 fathoms an example of 40 mm. occurred.

In August they reach 45 mm., most of the adult characters being present except the pigment. Some captured between tide-marks at Lochmaddy were, however, only 31 mm. In Guernsey, again, one of 116 mm. in July is probably 15 months old.

From what has been said above, the gunnel will be seen to belong to those shore-loving fishes with a demersal egg, the young of which instead of being brought up beside its parents, passes through an early migration which involves a pelagic sojourn in the offshore water, before eventually assuming its normal habits in the littoral region (cf. Herring, Sand-eels).

The Viviparous Blenny. (*Euchelyopus* (*Zoarces*) *viviparus*, L.)

This very interesting form has long been studied by naturalists since Dr Schoenevelde of Hamburg in 1624 brought it under notice, and Forchhammer of Kiel (1819), H. Rathke (1824) and F. Stuhlmann of Kiel (1887) have since more particularly dealt with the subject, the dissertation of the latter, which is illustrated by excellent figures, being especially noteworthy. One of us in 1885[1] also made some remarks on the ovarian young, in which Willughby's opinion of a winter breeding-season was corroborated, and the habits of the young, referred to below, were observed, while Mr Holt, who also studied it at St Andrews, followed with additional observations.

The viviparous blenny has a single roe or ovary lying along the middle line of the body, and in its walls the eggs are produced in the usual manner, but instead of being ripened and shed externally they are developed in cavities or follicles situated on processes or papillæ, fertilized in the ovary and then hatched, the young, moreover, being retained in the spacious ovarian chamber till they have attained a considerable size. They are then discharged externally to shift for themselves.

[1] W. C. M., *Ann. Nat. Hist.* June 1885, p. 430, Plate xvi. figs. 1 and 2.

If the adults are examined in November, December and January many are characterized by the great distention of the abdomen, due to the enlarged roe or ovary. The opinion of Willughby, therefore, that the species brings forth its young in the depth of winter, seems to be most in accord with the condition on the Scottish shores.

In the ovary the embryos, which correspond to the larvæ of other forms, lie over each other in a compact mass, yet the surrounding fluid in the chamber not only moistens the gill-apparatus, but enables them to glide over each other with ease. Stretching inward, moreover, from the thin wall of the ovary is a coating of long villous processes, which in shape are often clavate, narrow at the base and wide at the tip, many of the latter, indeed, forming somewhat flattened sucker-like surfaces. These are the processes on which the developing eggs were situated, and which, as will by-and-by be mentioned, afterwards perform important functions in regard to the embryos. In transverse section the wall of the ovary, to which the foregoing are fixed, presents a thick cellular (epithelial) layer on the surface, while the stroma beneath consists of mixed muscular and other fibres and cells. To this coat the membranous vascular processes are attached. When viewed as transparent objects the latter show a complete meshwork of anastomosing blood-vessels, which do not seem to be reduced to the size of capillaries, since in the smallest twigs several blood-corpuscles pass in column. A large volume of blood is thus swiftly carried into the organ. In transverse section, the vessels are arranged along the external margins of all the folds, so that they are in close contact with the fluid in the ovarian chamber. A thin epithelial coat with connective or basement-tissue beneath alone intervenes between them and the cavity. The walls of these blood-vessels are somewhat thick. In specimens examined immediately after the discharge of the embryos externally, the vessels are remarkably large and conspicuously gorged with blood. Whilst preserving in the main a longitudinal direction, each trunk has connections with the adjacent vessels at short intervals. The villous processes carrying these vessels fill the ovarian chamber at this time (after the extrusion of the young), while intermediate small eggs on short pedicels are studded on the surface of the thin wall.

In the middle of July in a female $8\frac{1}{2}$ in. long the single ovary forms a median and somewhat spindle-shaped organ placed under the kidneys and about an inch in length. Its greatest diameter is about $\frac{1}{5}$ of an inch. Numerous small ova are visible externally, through the transparent investment. On opening the ovary the small straw-coloured or deep yellowish eggs were attached by a pedicle to the wall of the ovary. The contents consisted of coarsely granular yolk. Most were nearly equal in size, and they were surrounded by a vascular investment showing beautifully reticulated vessels. Until the egg therefore arrives at a certain stage so as to come in contact with the spermatozoa no impregnation can take place; they hence are probably free in the cavity of the ovary before this occurs.

Somewhat previous to the foregoing (June 15), the two testes of the male were much enlarged, and contained many ripe sperms having the ordinary structure. In the middle of November, again, these organs had considerably diminished in size. One of the chief features of the male is the muscularity of the sperm-ducts, the terminations of which are stated to be capable of eversion, so as to facilitate the introduction of the male elements into the ovarian chamber. This also would readily be accomplished if, as in certain other marine forms, the sea-water containing them gained admission to the cavity of the ovary.

When the advanced young are in the ovarian chamber, the transparent fluid amidst which they lie presents altered blood-corpuscles, rounded bodies of similar hue, but somewhat less—apparently also blood-corpuscles undergoing degeneration, pale (blood?) corpuscles with granules internally, and many free granules.

In St Andrews Museum is a series of young viviparous blennies collected locally by Mr Holt. The smallest of them is about $\frac{3}{4}$ inch (20 mm.) in length and the yolk-sac is noticeable as a large spherical bag hanging under the throat. The stomach forms a second less conspicuous protruding sac behind it. As development proceeds the former decreases in size, and the latter increases till at $1\frac{1}{4}$ inches there is no trace of the yolk-sac but the stomach forms a conspicuous protrusion in the abdominal region. The ventral fins are then evident under the throat; they are really present at the earlier stage ($\frac{3}{4}$ inch) but are hidden by the large yolk-sac behind them.

Whilst still in the ovary of the parent, small dark pigment-spots (brown in spirit) make their appearance and they are scattered on the dorsal surface of the head and trunk, at a length of 1 inch; later they increase greatly in number especially on the back and sides of the trunk, and, in the largest, $1\frac{3}{4}$ inches (45 mm.), they have become definitely arranged. Numerous spots gathered into blotches cover the head and dorsal surface, being continued as a more or less distinct wavy line on each side of the median fin, whilst immediately below the lateral line is a series of large brown blotches with a tendency to be connected into a similar lateral wavy line on each side. The ventral surface appears to be almost devoid of pigment. Considering that all these young forms have been obtained by excision from the ovary of the parent, this presence and methodical arrangement of the pigment are noteworthy. The foregoing were all taken during the months of September, October, and November.

In January, young blennies three days old and reaching 2 inches in length were caught. The median dorsal fin has now a distinct indentation near its posterior end separating the caudal fin from the dorsal. The ventral fins have moved forward, lying somewhat more in front of the pectorals. Another specimen one week old, on January 10th, is no longer, but shows an advance especially in the pigmentation. The pigment-blotches united in a wavy series below the lateral line, and forming a succession of small curves with the concave side uppermost, are now completed above the lateral line by complementary blotches in the shape of curves with the concave side downwards, so that, following the lateral line, a broad chain of colour, the links of which are formed by rings of brown pigment, make a very striking pattern on each side of the little fish. The wavy lines formerly described as coursing along on either side of the mid-dorsal line tend to break up into diffuse spots, and a few faint bars of pigment are to be seen on the dorsal fin. The ventral fins have moved still further forward, their tips being nearly level with the base of the pectorals. The belly has greatly decreased in size, doubtless owing to the absorption of yolk, and the abdomen no longer protrudes. By the beginning of May, the young blennies have increased to $2\frac{3}{8}$ inches. The brown pigment is scattered diffusely as very fine dots over nearly all the head and trunk, tending thereby to disguise the lines and blotches described in the early stages. Traces of the former regular arrangement can, however, be still discovered.

'On extrusion from the protecting chamber of the parent, the young blennies show great activity: they vary in length from 41 to 51 mm. and are in some cases probably even longer. They seek the shelter afforded them by stones, crabs, submerged sticks, and similar structures, since they are greedily devoured by the young cod, haddock, whiting, and other fishes (including their parents): indeed, so much are they hunted that this fact alone shows how the numbers of the species are kept in check. When unmolested, as in a separate vessel, the young viviparous blennies stretch themselves along the horizontal branches of zoophytes, feeding on the hydroid polyps, and on the minute sessile-eyed crustaceans that lurk amongst them. The sides of the young are mottled with dark brownish touches on pale olive, the markings beneath the dorsal fin somewhat resembling arabic characters. A darker band runs along the lateral region, and on this are a series of silvery spots. The dorsal fin is marked by dark touches at somewhat regular intervals, as in the adult[1].' Except for the silvery spots, the pigmentation therefore does not differ essentially from that of the unborn larva.

In the following September occurs a specimen of $4\frac{3}{4}$ inches which probably represents the same series as those described before as about $2\frac{1}{2}$ inches in May. The trunk and dorsal part of the head are of a uniform brown tint, but the dorso-lateral blotches and the lateral chain of darker colour can still be distinguished, probably more clearly in the fresh specimen. The whole body is stouter and more like that of the adult.

[1] W. C. M. *loc. cit.*

The ventral fins are now much smaller in proportion than in the earlier stages, the rays may still be made out, though they are evidently undergoing the transformation into the tactile organs of the adult. They are scarcely smaller than in the adult, though presenting more of their original character, i.e. that of fins, with fin-rays and membrane. In the adult, as is well known, they appear as a pair of tentacular organs.

In the whole series may be noticed a proportionate decrease, with age, of the eyes and pectoral fins, a very general character in piscine development. The eyes are at first lateral but gradually approximate to a dorso-lateral position, so that they face upwards. The same change may be noticed in many of the small littoral fishes (see Weever).

We may observe that the viviparous blenny in common with most fishes has in its young stages a continuous median fin extending from the head backwards and round the tail forwards to the vent. Unlike the majority of fishes, this median fin does not break up into two or more dorsal fins, a caudal fin and one or more anal fins, but retains its simple larval continuity except a small dent in the posterior dorsal region which indicates the line of demarcation between the dorsal and the caudal. In its near ally, the shanny, as mentioned, the caudal fin is quite free, and the dorsal shews an indication of division into two, thus presenting an advance upon this type.

In estimating the age of this species at various stages, matters are complicated by its viviparous habit. A young blenny of 2 inches, newly 'born' in January, has already lived within its parent since the preceding summer and is probably about 5 months old, although by customary usage it would be termed 'one day old' or even less. For comparison with the oviparous types we must consider this stage to be about 5 months old and therefore the specimen $4\frac{3}{4}$ inches long probably represents the size attained a little over one year from hatching.

A specimen killed by frost in St Andrews Laboratory in February 1886 measured 10 inches, was full of young, and may be reckoned as in its third year, about $2\frac{1}{2}$ years old.

THE SHARP-TAILED LUMPENUS. (*Lumpenus lampretiformis*, Walb.)

This species was one of the additions to the British fauna made during the Trawling Expeditions for the Royal Commission (under Lord Dalhousie) in 1884[1].

A female captured off the Carr Lightship on the 23rd February[2] had the ovaries small and slightly developed, the eggs measuring from 0·2286 to 0·3048 mm., most ranging themselves round the latter diameter. They were therefore at a comparatively early stage, thus corresponding proportionately with those procured from the Moray Frith by Mr G. Sim, in which the roe was "pretty well advanced at the end of April, much more so than the milt of the males." Fries took a female 190 mm. long in January, and it had evidently just deposited its spawn; accordingly the authors of the *Scandinavian Fishes* consider the spawning-season to be winter. The ripe eggs are, however, unknown.

The Grey Mullet Family.

THE GREY OR THIN-LIPPED MULLET. (*Mugil capito*, Cuv.)

Day thinks this species breeds in winter. Raffaele refers to the pelagic egg (Plate II, fig. 3) of a species of mullet (probably *M. capito,* the grey mullet) procured in summer, and gives its diameter as 1 mm. and the oil-globule 0·20 mm., so that the latter is comparatively large. The pigment developed in the egg was black. The larva (Plate VIII, fig. 7) has a very large oil-globule at the posterior border of the yolk, and a considerable pre-anal fin separates the latter from the vent. Black pigment is dotted along the dorsum and head and forms a well-marked bar some distance behind the vent, with a smaller one midway between it and the tip of the tail, and yellowish pigment is also present. A speck or two occur in the dorsal marginal fin above the large bar.

[1] Dr F. Day, *Proceed. Zool. Soc.* 1884, p. 445.

[2] Vide 12*th Ann. Rept. Scot. Fishery Board*, p. 225. 1894.

Mr Williamson procured young specimens of 18·5 mm. on the 11th of February at Naples, of 30 mm. on the 6th March, and of 21 mm. in length on the 18th March at Magnavacca on the Italian coast. These appear to be the young of the previous season (summer), so that there is room for further investigation in regard to the spawning-period on our shores in contrast with that of the Adriatic. At the same place in April other young mullets reached the length of 55 mm.

Lesser Grey or Thick-Lipped Mullet. (*Mugil chelo*, Cuv.)

The young of this species about $\frac{3}{4}$ of an inch in length were found by Day in August swimming in shoals in Mevagissey harbour. When in the water they appeared to have a white spot on the back which disappeared when landed.

At Plymouth Mr Cunningham procured young examples of 10—11 mm. on 14th May, and $\frac{3}{4}$ inch in July and August, which he considered the young of the season, and that accordingly the spawning-period probably was April. When 10·5 mm. in length, on May 10th, the yolk was entirely absorbed. True fin-rays were only present in the tail inferiorly. The air-bladder was conspicuous, and the pectoral fins large. The colour was a general yellowish with numerous black chromatophores[1]. The following August they had reached $2\frac{1}{4}$ inch, in confinement, while one of similar age from the sea was about 3 inches.

The Stickleback Family. Gasterosteidæ.

The Fifteen-Spined Stickleback. (*Gasterosteus spinachia*, L.)

The stickleback, although not strictly a food-fish, is one of the humbler little members of the piscine race which inhabit our shores, and its life-history is fraught with peculiar interest, mainly because it has the habit of building a nest wherein the eggs are hatched.

[1] *J. M. B. A.* 1891—92, p. 73.

Perhaps the fresh-water sticklebacks and their life-history are more generally known than their cousins of the seashore: their little nests, carefully and jealously guarded, the pugnacious instincts of the males and their bright colours, are themes which have been dwelt upon by naturalists from time to time. The fifteen-spined, or marine species, whilst resembling its fresh-water allies in its curious nest-building propensities, does not develop any bright colours during the breeding-season, so that the sexes cannot be distinguished from one another by their hues; both are clothed in a sombre brown harmonising with their surroundings. The building of the nests or nidification, and the early stages of development have been followed in considerable detail by Prof. Prince at St Andrews Laboratory and the following account is mainly taken from his publication upon the subject[1].

The nests are to be found during May and June in sheltered rock-pools between tide-marks and often in the higher pools, and they consist mainly of the sea-weeds which are found in great profusion in such localities. Couch records the occurrence of a nest in the loosened strands of a rope, suspended in the water. The appearance of a completed nest may be seen in the Frontispiece to this work, and it will be readily noticed that in this particular instance a small plant of *Fucus* has formed the basis of the structure; this example measured from 8 to 10 inches in length and 5 to 6 inches in its widest diameter, and is now in the University Museum of St Andrews. To the *Fucus* are added small fragments of *Ulva*, *Corallina* and even *Hydrozoa* (Zoophytes) and the whole are firmly woven together by a glutinous iridescent thread-like material which is secreted and manipulated by the male. Upon completion of the nest the female deposits the eggs within the various cavities and interstices between its component materials, and the whole is then complete. The cavities are partly formed in the process of building and partly produced after completion of the structure by the help of the snout or even of the whole body; the parent-fish may often be observed passing through and through the nest, enlarging the cavities to suit its fancy.

[1] *Ann. Nat. Hist.* Dec. 1885, p. 487.

It frequently happens that an already completed nest is selected by a second pair, and the efforts of these in the way of building and of the deposition of ova are superposed upon those of the former couple, resulting in a very much larger nest. Naturalists were for some time puzzled by the fact that many nests contained a greater number of eggs than a single female could produce, but the foregoing explains the condition.

The binding thread is exuded from the anal region of the male and appears to consist of a modified form of mucilage; it is, when fresh, colourless and tenacious, and exhibits a delicate opalescence which disappears after a few days, leaving a greyish mass. On close examination, the cord appears to consist of several threads or strands, the cord being from ·004 to ·005 inch in diameter and the strands from ·0008 to ·0009 inch in diameter. Each strand may again be observed to be composed of an immense number of little fibrils of a delicate structure, running parallel to one another and to the long axis of the cord. The male appears to select a suitable mass of seaweed and attach to it by mere contact the viscid mass of mucus protruding from the urinary aperture and then by passing and repassing over and under the growing nest he binds all firmly together. The regular cross-arrangement of the threads is well shown in Prof. Prince's figure of the nest (Frontispiece).

The origin of the mucoid cords is very suggestive, for an examination of the male in the breeding season (Plate VIII, fig. 10) reveals the fact that the kidneys are swollen and the lining cells of the urinary tubules are found to be engaged in the production of the secretion. Whether they act as secretory cells as suggested or whether they themselves undergo a degeneration such as takes place in the case of many plant-cells in the production of mucilage, it would be difficult to say. In either case, the product of an excretory organ has been made directly available by the organism to subserve a function important to the well-being of the species, a striking example of the strict economy practised in nature. The mucous secretion passes from its point of origin down the ureters to the urinary bladder, in which it is stored up in large quantities. Finally it emerges through the urinary aperture, as an elastic tenacious thread. How far one would ask, does the pressure upon the bladder and accompanying distress to the system lead the male fish to build its nest, or how far does the latter act as an intelligent being with a definite purpose outside itself? Who shall say?

The straw-coloured, somewhat translucent eggs are of course of the demersal type, and are disproportionately large (·085 inch diameter). The capsule hardens slowly but when it does so it binds the eggs into a compact mass—sometimes three inches by two in diameter. 'The capsule is minutely punctured, the pits being in parallel rows,' 'it is hyaline, very dense and resistant.' A great number of small oil-globules are found inside the egg, attached to the investment by minute protoplasmic filaments. As in many demersal types the development was slow; the period of hatching being from twenty-five to forty days in the tanks with a temperature of from 40° F. to 50° F.

This difference in the rate of development of the eggs in the nest appears to be due to the fact that the outlying ova hatch more rapidly than those near the centre.

The embryo is peculiarly free from pigment in the early stages, the first appearance of black spots scattered over the dorsum being on the nineteenth day. The eyes, however, show black pigmentation in some degree as early as the fourteenth day. Three days after this the heart may be noticed as active, and a distinct circulation is established by the nineteenth day. We should emphasize the fact that a plexus of blood-vessels covers the surface of the yolk, a feature not uncommon in demersal ova but confined to that type (cf. Wolf-fish). By this date the embryo becomes very restless, movements of the tail and body frequently taking place.

The larvæ, upon hatching (Plate VIII, fig. 8), soon acquire a number of bright yellow pigment-spots scattered over the surface of the trunk, and interspersed amongst these are large stellate black spots, most abundant on the back and sides. The larval stickleback thus is adorned with the same two colours as occur very frequently amongst the pelagic gadoids and pleuronectids, but the little animal is far more active and able to take care of itself than is the case with its pelagic allies. When first hatched the median fin is continuous and the head-region is short and thick, elongating later to reach the adult proportions.

The exact size on hatching has not been mentioned by Prof. Prince, but when artificially extruded on the 5th June they measured about 5 mm. in spirit, and the yolk-sac was still large. They are found in the rock-pools somewhat later (25th June) measuring $\frac{2}{5}$ths of an inch (about 10 mm.) with the larval tail and are probably a week or two old. At 12 mm. a considerable portion of the larval marginal fin is still present—connecting the tail with the dorsal, and extending in front of the latter. The anal is connected in a similar way, and the pre-anal larval fin is distinct. True rays are developed in all the fins (Plate VIII, fig. 9). The larval tail is mainly distinguished by the notochord, for it is slightly marked, only a faint incurvation in the outline indicating it. Black pigment-specks cover the entire body, and occur ventrally as well as dorsally. No spines are yet present. Such examples are met with both in June and July, the foregoing having been captured on the 23rd July. At this date, others in the same pools are double the length, showing that the period over which the spawning of the various examples extends is considerable. At 19 mm. the adult characters are more or less present, except that the body generally is more slender, and the tail shows no trace of the larval organ. In an example of this length small ova like those of an ascaroid were present in the tail and in the dorsal fin. Similar forms up to 26 mm. occur in July, some even reaching this length on the 1st (in spirit). On the 6th August they are found 47 mm. long. Later in the season they are found in the harbour in October snapping at the small crustaceans which abound in certain corners. They then measure about 65 mm. Growth is thus fairly rapid.

In August specimens measuring 94 mm. occurred between tide-marks in Guernsey, such being probably 13 or 14 months old. In May a female of 135 mm. was probably 2 years old.

Amongst the *Elasmobranchii*, or cartilaginous fishes, it has been pointed out that the tendency for self-sacrifice for the sake of the young is exemplified in a gradational manner by various species, and it is especially important to notice that parental self-denial is not confined to this group but is also characteristic of such bony fishes as the sticklebacks, pipe-fishes, and the viviparous blennies. This feature is not therefore found amongst the larger and more powerful members of the Teleostean group, but amongst the little shore-loving forms in which the fierce struggle for very existence alongside their many foes in the prolific littoral region has called forth many and varied resources for protecting the species at its most vulnerable stage, viz. that of the eggs and young. We may recognize an essential difference between the Teleostean types referred to. In the case of the blennies it is the female sex upon which devolves the duty of nourishing and protecting the young, a duty which has its very first inception in all fishes by the supply of yolk from the female organism, whereas in the case of the sticklebacks and the pipe-fishes it is the males who in one case build the nests, who watch over the eggs and guard the young with a jealous eye, and if need be, with prickly spines, and in the other case protect the young in a ventral pouch.

The Wrasse Family. Labridæ.

The Ballan Wrasse. (*Labrus bergylta*, Ascan.)

Though by no means a common fish on the eastern shores of Scotland it is more frequent in the west and south. Nowhere is it more abundant than at the rocky borders of the Channel Islands, its dark form being familiar at low water as it glides for shelter into recesses. With so wide a distribution, therefore, it is remarkable that so little has been observed concerning its spawning, indeed in the recent edition of the *Scandinavian Fishes* the subject is only generally alluded to under the family as follows: "and some species are said to build nests of sea-weed for their ova." Couch states that the spawn is shed in spring (April), and the young, of small size, scarcely more than an inch in length, are seen about the borders of rocks at ebb-tide through the summer. Parnell only quotes the foregoing, adding, however, that "one in August was full of spawn ready for deposition."

Day gives the spawning-period in Galway as June, and along the south coast of Ireland from May till July. In June and July 1887 that patient and accomplished worker, the late Mr James Duncan Matthews, had the good fortune to secure by aid of the Fishery officer, Mr Rosie, several nests from Broadford in Skye. They were wedged, he narrates[1], about half-tide mark, into crevices of rock, which they partly filled, that is, rising at the back to the height of about 12 inches, and being curved in front. The outer (anterior) wall of one nest was 4 inches in thickness, and the nest was about 15 inches in long diameter, the projection in the centre of the crescentic wall being $6\frac{1}{2}$ inches. These somewhat massive nests were composed of numerous tufts of sea-weeds, such as *Corallina* and *Polysiphonia*—fixed principally at their bases by what appeared to be threads of semi-solid mucus. The officer had been informed that, before spawning, the fishes were observed to pass through these nests, and when the tide was rising they partly leapt out of the water to reach them. In the case of two nests sent by Mr Allan a hole was present, at least at one end. Mr Matthews found the eggs, which were still alive after transmission to Edinburgh, scattered over the whole nest and adhering to its material, but not very firmly. Their vitality is readily accounted for by their advanced condition. In size the eggs ranged from $\frac{1}{24}$th to $\frac{1}{25}$th of an inch. Mr Holt gives 1·01 mm. to 1·13 mm. The newly-hatched larvæ (Plate VIII, fig. 4) measured $3\frac{3}{4}$ mm. and were very active—wriggling continually to the surface with a rapid vibratory movement of the breast-fins, which like the tail had only embryonic rays. They were coloured with black and yellow chromatophores, which extended along two-thirds of the total length. Two rows of black spots and similar groups of dull yellow existed on each side, two on each segment, the dorsal being placed slightly in front of the lateral. They thus formed a lozenge-shaped figure when viewed from the side. An irregular and rather sparse distribution of pigment also occurred on the median dorsal fin anteriorly. The larvæ were very hardy—some surviving amongst damp sea-weed for ten days.

In general outline (to judge from Mr Matthews's figure) the

[1] *Fifth Ann. Report, Fishery Board*, p. 245, Pl. XI, 1887.

larval wrasse presents a somewhat deep body in lateral view and a lanceolate tail. The vent is rather behind the middle.

The earliest stage in our collection comes from Lochmaddy, North Uist, in August, and measures 9 mm. The tail is already complete, all trace of the larval organ being lost. They are, however, frequently met with in the pools at low water on the east coast, as at St Andrews, in August.

The next available stage is one of 11 mm., captured in St Andrews Bay in midwater in the middle of September[1]. This young wrasse shows boldly marked white touches on a greenish ground, variegated with brown pigment. The general hue, indeed, is greenish-brown with various bands and patches. Thus the head has two white touches (each somewhat crescentic in form) over the brain, and a transverse one in front of the dorsal fin. A brown band passes from the middle of the eye forward on the snout and in line with the brown bar on the tip of the mandible. Another brown bar extends from the eye downward and forward, a third touch occurs on the hyoid, and two or three bars exist elsewhere on the head. The eyes are pale greenish with golden arches superiorly, and a band of brownish-red surrounds the pupil, except inferiorly, where it is almost absent. This reddish belt has a process anteriorly and superiorly.

The body is conspicuously marked with eight white spots, the first being near the pectorals, the last in the centre of the base of the tail. These spots are situated above the lateral line. Five opaque-white spots occur above the former, two sending prolongations to the tip of the dorsal fin, and a third partially. Four specks of white are placed along the ventral margin, two lying in the basal line of the anal fin. A few minute specks occupy the space between the latter and the larger upper series. Large silvery patches, again, extend from beneath the eye to the end of the abdomen. A few brown specks appear on the ventral surface in front of the pelvic fins, and two boldly marked brown touches lie in the median line between the latter and the vent.

Besides the white touches which enliven the dorsal fin, an

[1] W. C. M. *Ann. Nat. Hist.*, Oct. 1887, p. 300.

opaque brownish one occurs in front. The soft rays of this fin have not yet attained the proportionately elongated condition of the adult. The breast-fins (pectorals) are large and somewhat transparent, their very rapid movements resembling those of the sea-horse and the pipe-fishes. A brown bar, however, marks their fleshy basal region, which in these and many other post-larval fishes is much larger in proportion than in the adult—a condition probably connected with increased functional activity. The ventral fins are opaque white, with a brownish belt in front (anterior rays); this belt, moreover, joins a brown band which proceeds upward to the base of the pectorals, where it bends nearly at a right angle straight backward to the posterior part of the abdominal wall. The anal fin has a brown patch (covering two rays) in front. None of the blue, yellow or orange, so common in the adult, has yet appeared.

After immersion in spirit only the dark pigment remains, and thus the body has a peculiarly blotched or speckled appearance posteriorly, while the head and abdomen are striped.

It is interesting that species frequenting rocks, as the lump-sucker and the present form, should display such vivid tints in the post-larval and occasionally in the adult condition.

At 12 mm. (from Lochmaddy in August) the conspicuous size of the last portion of the dorsal fin is noteworthy. The lateral line is visible at 18 mm., and the scales are present. At 23 mm. both scales and lateral line are better marked, and many of the adult characters have been assumed. All these are found in August.

THE CONNER. (*Crenilabrus melops*, L.)

Mr Holt observed ripe eggs of the Corkwing Wrasse on the 12th June in Clifden Bay, on the west coast of Ireland. They were colourless and translucent—without an oil-globule, and probably about 0·78 mm. In this and allied forms, List describes the capsule as divisible into two layers, an outer of regular hexagonal prisms, an inner stratified. The larva on hatching has a marked cranial flexure and a long pre-anal fin; while the yolk is pigmented with greenish and yellow, both of which colours also occur somewhat plentifully on the trunk[1].

Jago's Goldsinny. (*Ctenolabrus rupestris*, L.)

Fries and Smitt[2] observe that some females with running roe are only 80 mm. in length, and that the spawning-period extends from April to July.

Mr Holt obtained an egg which he identified with considerable certainty about the middle of June in Inver Bay on the west coast of Ireland. Its diameter was ·835 mm. The capsule was thin, and the yolk translucent and homogeneous. Black pigment appears in the embryo, when the free caudal region is noticeable, along the sides of the body and over the brain. The larva measures 2·8 mm. and is distinguished by an elliptical yolk, a pre-anal marginal fin, the vent in front of the middle, a double dorsal line of black chromatophores along the anterior two-thirds of the body. The notochord is unicolumnar in front, at the middle third it is two-celled, and posteriorly it is irregularly unicolumnar.

Specimens four inches long are met with in July off the Channel Islands, along with others about six inches.

The Rainbow Wrasse. (*Coris Julis*, L.)

Of the other representatives of this family Raffaele mentions that the eggs of what he deems the Rainbow Wrasse are included in a series ranging from 0·60 to 0·70 mm., with an oil-globule of considerable size, viz. 0·16 to 0·18. They were procured in spring and summer. The development of the egg is rapid, viz. in one or two days. The larva is characterised by scattered black pigment along the dorsum, an elongated yolk having the oil-globule at the tip, somewhat like the red mullet, and a pre-anal fin, the vent being about the middle of the body. After absorption of the yolk the post-larval fish shows minute serrations of part of the marginal fin dorsally and ventrally in front

[1] *Zeitsch. f. w. zool.* XLV., p. 623. Taf. 33, f. 38 and 39. 1887.

[2] *Scandinavian Fishes*, p. 18.

of the tail. Mr Holt[1] procured a very similar egg off the west coast of Ireland on the 20th June and 7th July. The larva emerged on the 3rd day and measured 2·44 mm. The flexure of the brain was less marked than usual. It agreed with the foregoing in the structure of the notochord.

[1] *Op. cit.*, p. 467.

ORDER II.

Anacanthini.

All the fin-rays soft and articulated, the ventral fins, when present, jugular or thoracic. Air-bladder without pneumatic duct.

A. Acanthini gadoidei.

Head symmetrical.

CHAPTER VIII.

The Cod Family. Gadidæ.

The Cod. (*Gadus callarias*, L.)

The cod, besides being one of the commonest and most important of our food-fishes, is also one of the most prolific. A single female has been known to carry as many as 9,000,000 ova, and the number usually quoted is as many as 7,000,000; the ripe ovaries of an average-sized female appear to contain any number varying between this and 2,000,000. Even the latter figure points to an enormous mortality amongst the young cod, especially in their earliest stages. It has been suggested that the greatest loss to the succeeding generation takes place at the very earliest stage of the egg, in that a large proportion of the ripe eggs discharged in the water are not fertilized by the spermatozoa and hence perish. Since the cod has been the subject of artificial hatching we have reason to believe that the proportion of ova which escapes fertilization has been largely over-estimated and that the 'slaughter of the innocents' must take place mostly in the stages of the developing egg and of the more or less helpless larval stage.

Taking into account the great number of ova and the fact that in this fish the female is usually smaller than the male, it is not surprising to find that, at the breeding season, the former becomes considerably distended with the hypertrophied ovaries. At this period slight pressure is sufficient to cause extrusion of the ripe eggs.

The ova, which are pelagic, are met with frequently in the inshore waters, but nevertheless there is strong reason to believe[1] that the spawning does not take place near shore but mostly in the deeper waters. On the east coast of Scotland the spawning-period extends from the beginning of February to the beginning of May, and probably a little later (see table), the part from mid-March to mid-April being the period of greatest activity. At exposed parts of this coast the mature fish may be found within a few miles of the shore, but on the west and south coasts the adults upon reaching sexual maturity move seawards and spawn in the open water, about a month earlier than those on the east side. Dr Fulton states that of a great number of cod and haddock caught and examined in St Andrews Bay and the Frith of Forth none were found to be mature; some approached maturity and others were spent. He states that the fishes on approaching maturity appear to leave the territorial waters and migrate seawards to the spawning-grounds, which vary from five or six to twenty or more miles offshore; some spawning cod are found as far as 170 miles out. There is reason to believe that the internal pressure exerted by the maturing sexual glands is the impelling force, and also that the fishes refuse food at this time, a habit which may also be connected with the same functional changes. At the expiration of the spawning-function the fishes doubtless return from this congregation to their old habits and recoup themselves.

The cod spawns off Gothland in April. On the American coast, Earll found the first spawning female in September, and in December half the specimens were in a spawning condition. Spawning attained its height in February and March, and some continued to June. He estimated that some examples take about two months to deposit their spawn, others a shorter period. The older generations, moreover, spawn earlier than the younger. The females keep near the bottom, the males somewhat higher. The smallest ripe male weighed 3½ lbs., the smallest ripe female 5 lbs. Hence he concludes that the males are ripe in their third year, the females only in their fourth[2].

The egg of the cod is, as already stated, pelagic, and has an

[1] Trawling Report, 1884; and Dr Fulton, 10th Report *Scottish Fishery Board*, p. 235. 1892.

[2] *Scand. Fishes*, pp. 477, 478.

average diameter of ·055 inches, 1·386 mm. (Cunningham 1·39 mm.) with no oil-globule (fig. 19, and figs. 24 to 34). It was described and identified by Sars as early as 1864. Ewart and Brook[1] have closely watched the spawning of this species in tanks. They state that the egg, after discharge from the oviduct, rises very slowly through the midwater, one example taking four minutes to ascend through $1\frac{1}{4}$ inch of water[2]. The micropyle is at the lower pole of the egg and fertilization takes place during the ascent of both sexual elements.

On the eighth or tenth day after fertilization (in April) the embryo hatches[3]. Three days before hatching, small round black chromatophores make their appearance upon the head and the dorso-lateral regions of the trunk, though as yet quite irregularly disposed: there is no yellow pigment in this species. The mouth is closed, and the vent is placed immediately behind the yolk-sac, and does not extend to the margin of the fin. The day after this the pigment makes its appearance in the eyes and becomes more abundant over the body, the chromatophores assuming a stellate appearance upon the next day. The pigment of the eye then becomes of a bright bronze hue, and the pectorals assume a bluntly lanceolate shape. Their length is about 4 mm.

The larval cod at first float more or less helplessly in the water, the large yolk-sac being usually uppermost. The pigment (all black) is aggregated into four conspicuous patches, one behind the pectorals, one towards the posterior border of the yolk and two on the tail. These patches or bands of black pigment upon the transparent larvæ give them a very odd and characteristic appearance, especially if they are viewed on a white background (fig. 3, p. 31). The aspect of the larval cod soon after hatching is seen in Plate IX, fig. 1, where the stellate black chromatophores arranged in bands are clearly indicated. In the cod, as in the haddock, the pigment never extends to the fins or over the yolk-sac.

[1] Ewart and Brook. *S. F. B.* 3rd Annual Report, 1885, p. 54.

[2] This is probably exceptionally slow.

[3] Development and Life-history of Food-Fishes.—McIntosh and Prince, *Trans. Roy. Soc. Edin.* 1887–88.

About the second day after hatching, the little cod have grown stronger; they assume the normal position with the yolk-sac ventral, and swim about in the water in straight lines. During this day and the next the circulatory system extends further and further towards the tail-end and the branchial system grows more complicated (Plate IX, fig. 2).

On the fourth day after hatching the yolk-sac has considerably diminished, the dorsal fin arises mid-dorsally and the integumentary vesicle (Ryder)[1] develops. This is a large expanded cap of cuticular tissue on the dorsal surface of the head, and is a well-marked structure in all the gadoids and some pleuronectids in confinement.

By the 6th day the larvæ have reached a length of about $\frac{1}{6}$ inch and the yolk-sac has almost disappeared, so that they may be regarded as coming to an end of their larval career about a week after hatching. At this stage, or soon after, they appear to move into the mid-water and later to the bottom, and it is rather difficult to develop them to a more advanced stage in the ordinary tanks of concrete or wood.

The latest stages in confinement showed complete absorption of the yolk-sac. The head becomes greatly enlarged and the lower angle of the jaw very prominent, with an upward slope of the mandible. The cephalic vesicle gradually disappears and a deep hollow occurs in the pre-maxillary region. The eyes are large, deeply pigmented and have a silvery sheen. The change in the character of the pigmentation from the four-barred condition to a more diffuse type is clearly seen. The two anterior bars gradually break up, being modified chiefly into a mass of black pigment lying immediately dorsal to the abdomen. The two posterior bars remain till later, but the dorsal parts of one bar slowly coalesce with those of the other so that eventually the post-larval form has a pair of longitudinal lines, dorsal and ventral, with no trace of the transverse bars of the larval form. Black chromatophores also occur on the head, the angle of the jaw and on the ventral surface of the abdomen. This stage in confinement did not exceed ·175 inch in length, but those at the same stage caught in the mid-water tow-nets

[1] Ryder, *Science*, VII. 1886, pp. 26–29.

attain as large a size as ·25 inch, showing the retarding effect that artificial rearing has upon the growth of these young forms.

At Plate IX, fig. 3, is seen a post-larval form which is probably a cod, about ·206 in. long and showing many of the above features; the stomach is brightly coloured (pinkish) with the oil of minute copepods which form the staple article of food of these little fishes. The eye has a purple sheen, and the choroid fissure is still prominent. Only two bars of pigment remain, and the chromatophores on the head and jaw have not yet made their appearance.

A stage later is seen at Plate IX, fig. 4. This little cod was about ·226 in. in length and shows well-marked pigment upon the head. The fusion of the two post-anal bands is clearly shown, and there are also traces of a row of lateral chromatophores in the caudal region. On the ventral surface black pigment-specks are dotted from the jaw to the vent—chiefly in the median line. The median fin is still continuous from behind the vent to a point dorsally above it, though carried by a slight membranous fold almost to the region of the head. The latter is very large, the mandible prominent, and the eye shows the choroidal fissure. This form might probably be about 3 weeks old. It has already assumed the uniform greenish yellow hue which is so marked a feature in more advanced stages.

In Plate IX, fig. 5, we have a stage ·33 inch in length. The median fin is continuous, though there are indications of the adult fins. The tail is still quite symmetrical. The ventral fins appear as a pair of buds below the pectorals, the head and eyes are proportionally large, and the mandible has the same vertical tendency, emphasised when the mouth is closed—as in the figure. The pigmentation is far more pronounced, and includes a number of yellow chromatophores scattered over the head and back (Plate IX, fig. 6). Soon after this stage the little fish makes rapid strides in its development and begins to assume the adult outline. The dorsal and anal fins split off from the continuous embryonic fin and permanent fin-rays appear. The tail assumes the adult form by greater development of the ventral (hypural) rays, thus bending the notochord dorsalwards. The eye is not so large proportionately, and the nasal region elongates, causing the mandible to become more horizontal in position. The pigment becomes more abundant and is chiefly distributed in dorsal, ventral and lateral longitudinal bands, together with large patches on the head and stomach. This represents a series having an average length of ·375 inch.

Shortly afterwards the young cod retire from their life in the upper water and seek the lower regions of the sea, where rapid growth takes place, the little fishes being nearly an inch in length at a date about 5 weeks after the stage last-mentioned. The transverse bars are visible in some, and the abdomen shows a pale orange-tint from the crustacean diet. The barbel now appears. As growth proceeds, the body assumes a brownish tinge and black pigment is aggregated along the sides. At the end of May and during June and July, these little fishes may be found in the shallow rock-pools at ebb-tide in company with green cod, from which they are readily distinguished (at 35 mm.) by the reddish hues of the head and the beautifully variegated body—which upon a pale greenish ground is dotted all over with black pigment-specks, while large ones occur over the brain, and on each side along the dorsum. The first two dorsals are also dotted with black pigment enlivened with touches of opalescent bluish; touches of the same hue occur at intervals along the middle line of the dorsum when viewed from above, one of the brightest being between the second and third dorsal fins. The pale patches between the dark bars on the sides have a beautiful pearly lustre. About eight dark blotches are placed along the median line, and as these are flecked by darker patches in the upper lateral region, they give a characteristic appearance to the fish. The upper lateral region (just above the lateral line) shows, from the operculum backward, nine dark spots. The first three are continued downward to the silvery belly and then cease. The rest have connections with a series of median spots—five in number—in the middle line, bands in several instances passing from two upper spots to one median, and again bifurcating inferiorly. The lower part of the gill-region and the belly are silvery, and in certain views the sides glance brightly like burnished silver with a slightly cupreous sheen. The ventral median line has on each side a band of pigment (continuous with the lateral bars described above), but the chromatophores are less regular than along the dorsum, though opposite the bases of the ventral fins the black pigment is uniformly arranged, apparently at the base of each ray. Pigment also occurs on the sides and under-surface of the lower jaw, and a thin dark streak passes a short distance backward in the middle line. The breast-fins are translucent, the rays only gleaming during their active vibratile movements. The first two dorsal fins have the blackish pigment best developed on the membrane between the rays—towards the free edge, the basal region being pale. The first anal fin is speckled with black anteriorly. The ventral fins are translucent with a few grains of white on the two outer rays, the second of which is now elongating. The tail-fin is free from chromatophores. The eyes show an iridescent orange-hue with minute specks of black on a silvery ground laterally; while from the dorsum they are blackish with minute iridescent greenish specks.

No tropical fish could present greater beauty of coloration or more perfect symmetry and grace of outline. They may be seen hanging in the water obliquely with their heads downward against the current, and measure from 1·37 to 1·9 inch in length. Their food consists of copepods, cirripedes, and young annelids. A young fish at this stage is figured in Plate IX, fig. 7. This remarkable coloration probably has an important protective function, the reversion to the transversely barred arrangement of the early larval stage being noteworthy.

Professor Sars has described later stages about 2 inches in length congregating together in shoals in early August. They appeared to frequent the algæ of the shore and growth was rapid. They are 4 to 5 inches or a little more in our country in October, 6 inches in mid-November, and 6 to 10 inches in mid-December. He supposed that a continual succession of shoals frequented the bottom algæ, these migrating outwards again upon attaining a greater size. Apparently two varieties of these algæ-fish, differing in colour, occur, the reddish-yellow fish frequenting the algæ and feeding on the red crustaceans, and the green or grey forms feeding in sandy spots on annelids and young *Cotti*. Similar stages are abundant on our own shores. In February or approximately one year from hatching, the codlings are about 1 foot long, and during the second year they migrate seawards to return in their third or fourth year as full-grown cod, a second migration further seawards taking place at the time of spawning. The cod does not appear to be mature till the third year. The rate of growth seems to be exceptionally rapid, a medium-sized codling being capable of adding 6 or 7 inches to its length in the course of a single year.

The subject of the rate of growth of fishes, although very important is still in an uncertain state and further data are needed. It is more than probable that the size attained by a fish before sexual maturity varies within wide limits and is largely determined by the nature and quantity of food, and by environmental factors.

Hence experiments with fishes growing under artificial conditions must not be allowed to have too much weight, although their value is increased the more closely the natural conditions are imitated.

Dannevig[1] succeeded in rearing a number of young cod in a large confined basin with a capacity of 2500 cubic metres, and noted carefully the growth in length. The following table, corrected to inches, is taken from his paper :—

Date.	Age.	Size in inches.	
April 26	Hatched	·117	
May 3	6 days	·195	
„ 16	19 „	·273	
„ 18	21 „	·332	
„ 21	24 „	·351	
„ 31	1 month 5 „	·390	
June 3	1 „ 8 „	·468	
„ 6	1 „ 11 „	·585	
July 12	2 „ 15 „	2·145	·585
August 12	3 „ 15 „	2·73	·585
Sept. 12	4 „ 15 „	3·315	
Oct. 12	5 „ 15 „	4·485	1·17

[1] See abstract of Dannevig's Report by Walter Webster, *Scottish F. B. Report*, 1886.

Thus the young cod as hatched is about $\frac{1}{10}$th inch in length, and roughly doubles this figure in about a fortnight.

"The further growth is extremely diverse in the several individuals, which may depend on difference of race as well as on the greater or less quantity of food the young creature manages to procure, and consequently, when I give a size, it must be understood as an average. Between June 6 and July 8 there is a great increase in the development (see above), which may be explained by the fact that the young begin to eat the food flung to them in considerable quantity twice a day."

It is interesting to note that at the expiration of about a month the young fish is roughly half-an-inch in length and that, after the increase above referred to, the two next consecutive months present each a further growth of half-an-inch per month, whilst this figure is doubled during the month next following. As regards the growth after October, Dannevig remarks:—

"From the middle of October to the middle of February the growth has been much slower, for reasons which are very easily explained. The fry of the cod in the open sea set out for deep water when the surface water begins to get cold, which generally happens in November...Such an emigration cannot take place in the basin except as far as they seek the deepest hollows, where they usually remain; that this must exercise a great influence on their development was foreseen. In cold weather they entirely abstain from food."

Thus the growth-rates become unreliable after October, and even before this the sizes given are probably below the *natural* average. The longest first-year cod caught at sea in mid-October was just over 6 inches in length. Off our shores cod of 8 inches are common in November, though others may be only $4\frac{7}{8}$ inches. After February, Dannevig notes another rapid growth and states that many of the codlings are over 1 foot in length by June, or 14 months from the date of hatching.

The cod attains maturity at an average length of about 20 inches.

THE HADDOCK (*Gadus Æglefinus*, L.)

The haddock is not only in size, but also in many other features, a fish intermediate between the cod and the whiting.

In the adult, the male is usually slightly the larger, and is found, as is the rule amongst gadoids, in the proportion of two to three. The ovary of a mature female may contain from 2,000,000 to 500,000 or 170,000 ova, which ripen in series and are extruded intermittently.

The egg of the haddock is the largest of the gadoid group and is also laid the earliest; its diameter is on an average ·058 in. (1·458 mm.).

This large pelagic egg, in company with that of the plaice, is one of the very first which occurs off the east coast, a few making their appearance towards the end of January. From this date to the end of May the egg of the haddock is of frequent occurrence, but the majority of the females appear to spawn from mid-March to mid-April, and in some areas these eggs are found in vast numbers.

With so great a variation in the spawning-season it is not surprising to find a like difference in the length of the period of incubation; the earliest eggs require as long as three weeks, the latest being hatched in the very short space of 6 days.

As regards the spawning-grounds and habits of migration at the breeding-season, the statements previously made concerning the cod seem to apply equally well to the haddock.

Thus the ripe fishes of both sexes congregate in the offshore waters on spawning-grounds varying from 5 to 20 miles out, though occasional specimens are caught as far seawards as 60 miles. On the west coast, the same congregation occurs perhaps even to a greater degree, and at an earlier period. After spawning, the fishes are out of condition as food, being much emaciated (in a less degree than in the case of the cod), but by-and-by they recoup themselves. The 'spent' fish are familiar objects to the fisherman, and are not readily saleable.

The egg of the haddock (Plate III, figs. 1 and 2) is distinguished from that of the cod in its early stages only by the difference in size (see Table). In the case of an egg fertilised on the 20th of March, the embryo was hatched in twenty days. On the fifth day there are indications of four or five vertebral segments, and a few black pigment-spots appear on the sides and back of the embryo. The blastopore closes on the 11th day and on the 12th there are indications of Kupffer's vesicle. By this day an increase of the black pigment-spots has taken place. These are large and star-shaped and are in great abundance in the dorso-lateral region above the breast-fins.

By the 15th day, the embryo has increased considerably both in length and in the size of the head-region, and by the 17th day, the heart beats about 30 to the minute, and embryonic rays appear in the fins. The eyes then become black from the presence of pigment, and the breast-fins have a distinct rim.

On the 20th day, the larva emerges (Plate III, fig. 3). It is then about ·1 inch (3·5 to 4·1 mm.) in length. When the larva is at rest, the buoyancy of the yolk-sac causes it to float uppermost, but in its intermittent attempts at progression in the comparatively still water it keeps itself in the normal position. Black spots are aggregated behind the ears, and a paired lateral row of the same pigment runs from the abdominal region nearly to the tip of the tail. Over the surface of the yolk is seen a delicate polygonal pattern or protoplasmic net-work, which is also found in the flounder.

The appearance of the larva on its escape is seen in Plate IX, figs. 8 and 9. It has, in common with the cod, the characteristic absence of all brightly coloured pigments, but can be readily distinguished from the latter by the fact that the disposition of the black pigment shows no tendency towards transverse bands, which have been already emphasised in the account of the development of the cod, though the general plan is similar. The eyes in this figure show black dots in the iris and are thus in an earlier stage than those of the cod. They are often more pigmented than in this specimen, and Holt describes newly hatched larval haddock with densely black eyes (west coast of Ireland). On the other hand, his larvæ appeared to have less pigment on the dorsal wall of the abdominal cavity. In June they hatch in the short period of six days, and after a week they take to the bottom of the vessel in still water, moving actively when disturbed. At rest they hang with the front end inclined downwards, as is also the habit in other very young fishes under these conditions, and are difficult to see. The prominent diagnostic features are the very large and pigmented eyes, the black pigment-spots on the head and neck, on the dorsal wall of the abdominal cavity, and along the ventral muscle-plates behind the vent. There is no pigment on the dorsal region posteriorly, and the yolk-sac and marginal fins are also free from black chromatophores. As in the cod, the vent is placed immediately behind the yolk-sac, and does not reach to the edge of the marginal fin.

When five days old the skeletal elements of the mandible have considerably elongated, and the abdominal pigment has increased. The oral chamber has burst through. The mouth gapes, but only erratic movements of the parts take place. The otocyst presents a ridge growing up from the floor, and a chamber descending from the roof, the otoliths lying on each side of the former. A lenticular mark indicates the anterior nares. On the seventh day blood enters the heart, and the circulation becomes active. The black pigment over the brain and the medullary region, and the roof of the abdomen, is still characteristic[1]. The appearance of the young haddock on the eleventh day is seen in Plate IX, fig. 10.

The later post-larval stages of the haddock up till now have not been recognised as such beyond dispute, and they have probably been often confounded with those of the cod. It can hardly be supposed that the post-larval stages of so common a form can have defied all means of capture, and the similarity of these two fishes would lead us to suppose that in the stages in which the larval cod have lost their early transverse bars the resemblance would be closer. Sars held that the post-larval haddock could be recognised by their shorter and stouter form

[1] McIntosh and Prince, *Researches*, p. 823.

—amidst the swarms of young fishes on the spawning-grounds of Lofoten, and such would appear to be the case. Whilst the marginal fin is still continuous the black pigment of these shorter forms of 7—8 mm. is scattered over the head, along the dorsal and the ventral edges, with a few specks on the sides posteriorly. At 11 mm., besides the foregoing, a very distinct area of pigment-points occurs behind the breast-fins. A few grains also appear on the latter and on the ventrals, which at this stage form short fins with true rays. Some fin-rays are now present in the second and third dorsals and in the two anal fins as well as the tail, but the first dorsal has only embryonic rays. The body is comparatively short and thick and the head large. Such forms do not, so far as present experience goes, appear in numbers inshore, but frequent the fishing banks offshore, especially in May. Instead of seeking their way inshore, indeed, like the cod and green cod, the little haddock frequent the deeper water, and they are abundant from 25 to 30 miles E. by S. of the Island of May and near the "long forties," where the mid-water net captures them along with swarms of young whiting in the first weeks of July, and varying in length from 24 to 80 mm., as well as, in all probability, on both sides of these sizes.

At 24 mm. the little haddock is distinguished at once from the whiting of the same length by the more compact outline; by the shorter first anal; by the longer ventral (pelvic) fins, which (long second ray) reach nearly as far backward as the tips of the pectorals; by the slightly larger eye; by the presence of more dark pigment generally on the fins, the ventrals being quite pale in the whiting. On the other hand, the black pigment on the head of the whiting is sometimes better marked, and the same may be said of the tip of the snout (the premaxillary and the mandibular regions). Both species have the sides of the body dotted with pigment-specks from the breast-fins backward, and dorsally forward to the snout, the belly being pale and slightly silvery. The mandibular region, inferiorly, in the whiting shows more numerous scattered black chromatophores. Moreover, above and a little behind the breast-fin of the haddock is an area dotted with very fine black chromatophores, the future black spot, though not at present conspicuously differentiated. Lastly, the barbel in the haddock is generally more distinct. The vent in the latter is nearly in the middle of the body, whereas in the whiting it is close on the anterior third, and thus the body of the whiting is proportionally elongated. From a cod of the same length the young haddock is diagnosed by the shorter, thicker body; by the smaller barbel; by the more evident separation of the second and third dorsal and the two anal fins; by the longer ventral fins; and by the absence of the tendency of the black pigment to form a line along the middle of the body. Further, the chromatophores on the sides of the cod are less numerous.

At 29 mm. the general bulk of the little haddock, in contrast with that at 24 mm., has notably increased, and the shape and curves of the head have been modified. The ventral fins are proportionally longer, a feature doubtless associated with the more purely pelagic life followed by the species at this stage. The pigment is still present in the ventrals.

From the whiting of the same size it is recognized by the permanent characters in relation to the first anal fin, and by the much longer ventral fins, the second ray of which projects considerably beyond the rest, as well as by the more compact outline, and the more distinct barbel. At this length also the aggregation of the dorsal pigment in the whiting to form the characteristic bars at once separates them. The bones of the mouth in the haddock are also better pronounced. The area above the pectoral with the minute black chromatophores —though present—does not attract special notice in scanning the fish (haddock). All the fins of the haddock are largely developed. From a cod of the same length, the characters formerly mentioned still hold, but the barbel in the cod is now much larger, and the disproportion between the pectoral and the ventral fins greater. The second ray of the ventral in the cod is longer than the first. The tendency of the lateral pigment to form bars in this species is also diagnostic.

In the *Scandinavian Fishes* it is stated that at Spitzbergen in September the young haddock are about 35 mm. long, while

Collett found them 40—50 mm. long in Christiania Fjord on the 14th of June.

At 39 mm. the chief changes in the young haddock are a diminution of the proportional length of the ventral fins, the acutely-pointed condition of the first dorsal fin, the increase in the silvery hue of the sides, and the development of the scales. The area of finely dotted pigment above the pectoral is more densely covered. In contrast with a whiting of the same length it is a much stouter fish, the head and eye are larger, the belly more capacious, and though in both the tips of the pelvics (long second rays) project beyond the vent, yet the length and strength of the haddock's fins are characteristic, and they also retain their pigment. Parasitic *Caligi* further seem to be partial to this species. The long, sharp, recurved teeth of the whiting are more prominent than those of the haddock. The vent of the former is considerably in front of that of the latter, and the first anal fin is fully developed. There is little chance of confusion with the young cod of similar length, since, before it reaches this size, its sides are beautifully dappled, its mouth larger, the barbel much longer, the ventral fins do not reach the vent, and the body of the fish is less compact, while the head has a different outline. No black pigment occurs on the rays of the pectoral or pelvic (ventral) fins. The dusky hue of the green cod and pollack, both of which show the median line of black pigment along the centre of the body posteriorly, readily separates them. Both lean to the cod in regard to the proportions of the pectoral and the ventral fins.

The little fish grows rapidly, and at 53 mm. (about two inches and a quarter), the dark mark behind the shoulder—so characteristic of the species—is readily seen with the unaided eye. The cupreous lustre appears to bring out the pigment, since the condition is just as in the smaller forms, viz. a closer arrangement of minute black pigment-specks. The pectoral fins have a yellowish-brown hue with black specks on both sides as before. The ventrals are pale, but they still have black chromatophores arranged in a linear manner in the centre. The head and body are minutely and uniformly dotted with black, while the brain is reddish. The eyes are large and together with the sides have a silvery sheen. The barbel is small in contrast with that of the cod. The ventral fins are now proportionally shorter, a clear space existing between them and the vent. The lower jaw is underhung, as in the adult.

The view of Sars that the young haddock seeks shelter under medusæ until about 50 mm. long is, as a general rule, not more tenable in our waters than in the case of the cod.

There is no need to describe minutely the various points of difference between this species, the whiting and the cod, but a few remarks may be made on certain evident modifications occurring during the growth of the three forms at this stage. Thus, whereas the pale ventrals of the whiting fell short of the vent in the former stages, they now extend beyond it, the second ray, with its sensitive tip, so carefully described in various fishes by Mr H. C. Williamson, being proportionally longer than in the haddock. On the other hand, the second ray of the somewhat short ventrals of the cod far exceed both, such being probably of great service in its haunts inshore amongst the tangle-forests, and tidal runlets at low water. The large mouth of the cod, its long barbel and characteristic head are noteworthy, as also are the prominent teeth of the whiting.

Up to this stage not a single young haddock has ever been captured by the various nets so constantly in use during inshore observations. It is a deep-water fish, of whose existence fishermen as a rule are not cognizant, unless when casually dropped on deck from the mouth of a larger form captured by the hook, or by the trawl.

At 80 mm. (about three inches and a quarter) the blackish mark behind the shoulder is very evident, both in life and when preserved. It is due, as formerly, to a dense aggregation of minute black chromatophores. The cupreous sheen of the little fish is well-marked. The black pigment on the pectorals, ventrals and first anal is also characteristic. The tip of the second ray of the ventrals is proportionally more elongated than in the previous stage, perhaps in connection with a change of habit either towards the bottom or the shore. This sensitive ray is fully as long as in a whiting of the same size, but whereas in the latter it extends considerably beyond the vent, it falls considerably short of it in the haddock. The cod of the same length has a much longer second ray than either.

At this stage also they seldom come under the cognizance of any fisherman.

Towards the end of the same month, however, viz. on the 30th of July, specimens of 4 inches occasionally take a hook or are entangled in *débris* in a trawl. The ventral fin is proportionally shorter (though the second ray is still long), a larger interval occurring between its tip and the vent.

In August the haddock of the season range from 3½ to 6 inches, all the specimens in the laboratory at and above 4½ inches being from the hooks of the liners. It is probable others will extend on each side of these limits. The long ray (second) of the ventral fin is still prominent.

The growth of the haddock is thus rapid, more rapid than at first sight it would seem.

In September the specimens from the hooks range from 5 to 6⅝ inches. Fries observes that in October and November small haddocks of 100 and 150 mm. (4—6 inches) are occasionally captured on the coast of Bohuslän, and this agrees with what Yarrell formerly mentioned. In November some reach 7¼ inches; while in December the limits in the collection are 5¾ and 7¼ inches.

The following year the young haddocks are familiar to fishermen as the 'summer haddocks'—immense shoals seeking the inshore waters after sand-eels and other prey, and often proving a nuisance to the liners, occasionally even to trawlers. In May and June their length ranges from 7½ to 9 inches or thereabout. Their early life is thus spent in the deep water offshore, as all our former experience demonstrated, and as also shown by Dr Fulton in 1890[1]. If special nets, such as the mid-water net, are used over the various fishing-banks offshore, multitudes of little haddocks are obtained, but otherwise they do not come under the notice of fishermen until they are able to take a hook, that is, when about 4 inches in length.

[1] *8th Ann. Rept. Fishery Board*, p. 174. 1890.

We thus have data by which we can form a fair idea of a young haddock's rate of growth for, at least, the first year. The July series of 4 inches can be 5 months old, allowing for a spawning-period from February to May, inclusive, but are probably less (see below). The young fishes at the end of August, from 3½ to 6 inches in length, may be from 3 to 7 months old, though they are probably within narrower limits than this. The September series of 5—6½ inches may be from 6 to 8 months old, and the December forms of 5¾ to 7¼ inches are between 7 and 11 months old. The young haddock of May and June in the following year, from 7½ to 9 inches, are, according to the spawning period, 13 to 19 months in age.

From these facts we may note that the rate of growth of the haddock is very rapid during the summer of the first year, and might roughly be given, as on an average, nearly one inch per month; but that on the approach of winter with its scarcity of food and low temperature the rate of increase falls, and young haddock nearly a year old (11 months) are sometimes less than 7½ inches in length. The effect of the seasonal variations is still more manifest through the spring, so that by May and June young haddock which may well be 17 months of age, but not older, are about 9 inches in length, the proportion of inches to months being now reduced to nearly one half. The haddock appears to attain maturity in its third year, and its growth-rate is probably not unlike that of the cod, but rather less.

The Bib. (*Gadus luscus*, Willughby.)

The bib is a form that seldom comes under observation on the East Coast, but the remark by Day, that it spawns towards the end of winter, would seem to be warranted. At any rate on the 29th February, 1888, a ripe female occurred at St Andrews. The egg-capsule is finely punctured, and the micropyle resembles that of the haddock. The egg is comparatively large, ranging (in spirit) from 1·14 to 1·16 mm., so that when fresh this size may have been exceeded by ·076 to ·114 mm. Mr Cunningham found certain eggs in the tow-net on January 20th off Plymouth—which he provisionally identified with the bib, giving the diameter as 1·13 mm. In this case the larval fish resembled a whiting. He also had an opportunity of measuring eggs from a ripe bib in a tank at Plymouth in March, and found the diameter 1·05 to 1·15 mm.[1]. Dr Sauvage found ripe forms at the same period (February) at Boulogne[2]. The milt of the male resembles that of the haddock and its allies. It is largely developed at the end of December. The Scandinavian authors simply state that the spawning-season occurs in spring.

Mr Cunningham procured specimens of 2·5 inches on the 17th June, others 4·6 inches on September 5th; while on October 2nd, they ranged between 4 and 5 inches, and he assigns an age of 3, 6 and 7 months respectively to these examples. On the other hand one of $3\frac{5}{8}$ inches in January was probably seven months old, and another 4·9 inches on June 17th he thinks is a year and two months old. Specimens of the same age he says are taken by the deep-sea trawlers in depths up to 30 fathoms. In October the young bib in the Thames range from $4\frac{1}{2}$ to $5\frac{1}{4}$ inches, at which size they are destroyed in considerable numbers by the shrimp-trawlers.

The Poor-Cod. (*Gadus minutus*, L.)

This, besides being the smallest, is also one of the most widely distributed of the gadoid fishes. Its development and life-history seem to resemble those of the whiting more than any other of the family.

The egg (Plate III, fig. 6) which was first described and figured by Raffaele, is small, seldom exceeding ·039 inch in diameter, and there is no oil-globule. In other respects it closely resembles the egg of other gadoids.

The spawning-period is late and may extend to June, whereas Raffaele found the eggs in early spring at Naples. In the *Scandinavian Fishes* it is said to spawn in the first days of spring, as in February and March the ovaries are full.

[1] *Journ. Mar. Biol. Assoc.* 1889–90, p. 375.

[2] *Ann. de stat. Aquiq.* 1893, p. 93.

Risso gives April and May as the months in which the Mediterranean *capelan* is full of roe[1].

The distribution of the ova appears to be like that of the whiting, for instance, whilst in the region of the Forth the eggs of the cod and the haddock are found mostly outside the Island of May, those of the poor-cod and whiting, although occurring in numbers with those of the cod and haddock further seawards, are often found in the upper reaches of the Frith. In estimating the importance of these facts the effects of wind-currents and tides must be taken into account; but we have important data, as stated above (see whiting), which lead us to believe that the whiting may spawn nearer inshore than the cod and the haddock; and this, taken along with the fact of close agreement in general distribution of the eggs of this species and of the poor-cod, clearly points to the assumption that the poor-cod is also a species which often spawns rather nearer shore than its larger relatives, the cod and haddock. The development in this species is rapid, correlative with the late spawning-period, and the early stages present no striking peculiarity. A marked characteristic of the young stages is the occurrence of yellow pigment dotted profusely over the head, body, and yolk-sac of the embryo; in other respects also the young larva, first figured and described by Raffaele as transparent and as if devoid of pigment, when hatched, resembles that of the whiting. The eyes are silvery-greenish and the yellow pigment is diffuse. Its length is ·108 inch or about 2·75 mm. Holt. A dorsal and a ventral longitudinal row of black spots end abruptly before reaching the tip of the tail, as was noticed in the larval whiting. There are also a few stellate black chromatophores dotted over the head. (Plate X, fig. 1.) The yolk-sac, with a diameter of one-half the total length of the larva, is proportionately rather large.

During the next five days there is a rapid development of the organs, and absorption of the yolk. The black pigment becomes more abundant and extends to the yolk-sac. (Plate X, fig. 2.)

[1] *Scandinavian Fishes*, p. 497.

By the seventh day the larva has absorbed the whole of its yolk, and rests upon the bottom of the vessel. The breast-fins, directed upwards, are fan-shaped. The eyes are silvery by reflected light, but by transmitted light they appear of a glittering bronze.

The yellow colour now becomes less conspicuous, the black, however, increasing (Plate X, fig. 3.). The post-larval poor-cod at this stage are very active and difficult to observe. Further development has not been studied, but a decrease of the yellow pigment and an increase of the pectoral fins occur.

The later post-larval forms have not yet been identified, though they may occur with post-larval whiting.

The older stages are not uncommon in the Frith of Forth and St Andrews Bay. Thus specimens of $1\frac{1}{2}$ to $1\frac{3}{4}$ inches occur in the former area in October, and larger examples (about 2 inches) in November. In August of the following year specimens of $4\frac{1}{2}$ to $5\frac{1}{4}$ inches, and others nearly 6 inches, were taken in St Andrews Bay.

The young poor-cod found in October ($1\frac{1}{2}$ to $1\frac{3}{4}$ inches) must be at least three months old, and those in the next month (2 inches) of a minimum age of 4 months. It is probable that those occurring in the following August are about 14 months, if not more. These facts point to a slower rate of growth for the poor-cod than for the cod, haddock or whiting, the one-year-old poor-cod probably being on an average about 4 inches in length.

Mr Cunningham found at Plymouth specimens one inch long on May 28th, from 1·6 to 2·9 inches on June 17th; he considers the former 8 to 12 weeks old, the latter about 3 months. Those of 4·5 to 6·5 inches on 9th July he thinks are 1 year and 3 months; those of 5·6 to 7·5 inches on April 19th, 2 years; and on June 17th, those of 5·4 to 5·8 inches, and again of 7·8 inches, are respectively 1 year and 2 months, and 2 years and 2 months. He also recorded that specimens from 4 to 6 inches, and just over a year old, were placed in the tanks of the laboratory in the summer of 1889. They produced eggs the following March.

The Whiting. (*Gadus merlangus*, L.)

This little relative of the cod differs considerably in its development from it.

The male whiting is usually rather smaller than the female, the opposite relation holding in the haddock and cod. A ripe female may contain as many as 300,000 ova, a large number, but many times less than in the case of the cod. Correlated with this we find the fact that the female is never so abnormally distended at the breeding season, the weight of the ripe ovary being only a small portion of the total weight of the body, whereas in the cod it may reach as high a proportion as $\frac{1}{5}$th. Hence the whiting is not so affected by the effort of spawning, and 'spent' whiting are commonly caught and sold for consumption.

The spawning-period appears to extend on the east coast from March to June, but principally during April and May, so that, as will be seen by reference to the table, it is rather later than that of the cod.

Again, the whiting does not appear to migrate so far seawards for the purpose of spawning as its allies, the cod and the haddock, mature females being found in the Frith of Forth, and not further seawards than about 60 miles offshore. Much reliance, however, need not at present be placed on these limits. The authors of the *Scandinavian Fishes*[1], on the other hand, observe that the whiting does not spawn in so large companies as many other species, but retires into deep water, so that more information is required on this point.

The egg of the whiting (fig. 16, p. 68) closely resembles that of the other gadoids, but is slightly smaller than that of the cod, having an average diameter of ·0476 inch (1·204 mm.). Holt (Ireland) gives 1·07 to 1·14 mm. There is no oil-globule. Development is rapid and the early stages conform to the gadoid type (see Chap. V, and figs. 16 to 23). By the eighth day yellow chromatophores appear upon the dorsal region of the larva, and upon the yolk-sac, a number of

[1] p. 491.

minute spots of yellow pigment also invading the marginal fin. This early appearance of yellow pigment is a remarkable specific feature of the whiting, and its presence serves as a ready means of distinguishing the embryo from that of a cod or a haddock.

It is customary amongst the zoologists of to-day to attempt to explain the presence or absence of particular pigments in animals by the influence of natural selection upon variations which may be advantageous in the particular environment of the organism, but it is difficult with our present knowledge to assign any direct advantage to the embryonic whiting by the presence of yellow pigment, which would not apply equally to the cod. It is hardly possible that the later breeding-season and greater proximity to the shore can be, at any rate, direct factors in causing this diversity.

The larval fish (Plate XI, fig. 1) emerges on the tenth day (in April), and measures 3·2 to 3·5 mm. A noteworthy feature is the pale greenish yellow tinge, due to the fine yellow pigment. The larvæ are beautifully translucent and move about actively in the surface-water.

Plate XI, fig. 2, shows a young whiting at the close of the larval period; it is the latest stage yet reared in confinement. Besides the diffuse yellow pigment there are double rows of black chromatophores, the outer one in each series being most prominent, that lying dorsally extending to the front of the head and that ventrally becoming very conspicuous over the stomach. The rows come to an abrupt termination before reaching the tail, a frequent character in other species. Scattered masses of black chromatophores on the lower jaw and ventral part of the abdomen complete the coloration. The eye is of a beautiful metallic blue; the lower jaw protrudes beyond the snout and is without the upward angular inflexion which gives so peculiar an aspect to the larval cod. A large serous cavity is present on the dorsal region in those in confinement. We may note that there is no indication whatever in the larval whiting of the barred or striped appearance which is so marked in the little cod, and indications of which are also found in many pleuronectids.

There is scarcely a gap in the sequence of stages observed from larval to post-larval forms. In the latter stage the whiting probably closely resembles its congeners the cod and haddock, the brighter colours which are possibly more prominent in the former, being mostly lost before the little fishes come under observation. The pressure to which these minute and delicate forms are subjected in the deeper nets—especially amongst crowds of jelly-fishes—alone would suffice to alter their external characters, and the handling of the heavily laden net increases the injuries.

At the length of 9 mm. (·35 to ·47 inch), the young whiting can be distinguished, and great numbers occur in July and August in the mid-water net 25–30 miles south-east of the Island of May. About this length the dorsal and anal fins form a continuous web with only embryonic rays, but the caudal has its permanent rays developing distinctly, and in a somewhat symmetrical manner above and below the tip of the notochord, which here passes straight backwards to the middle of the tail. In spirit, a considerable amount of black pigment occurs on the dorsum of the head, and some at the tip of the snout. On each side of the dorsal median fin a bold line of the same pigment stretches from above the pectorals to the base of the tail, the line along each side of the ventral median fin being much less distinct, though the broad band of black chromatophores which runs backwards above this is more conspicuous than that on the side below the dorsal black line. The lateral pigment is mostly in a single and comparatively short line of chromatophores, whereas the lateral ventral is formed of two or three irregularly distributed from above downward, and is longer. Ventrally a line of chromatophores follows the mandible on each side; part of a ʌ is similarly outlined on the hyoid, a group occurs below and in front of the breast-fin, and a median stripe runs along the abdomen.

Between the foregoing series and 11 mm. permanent rays appear in the dorsal and anal fins, the first dorsal being somewhat behind the others in developing them, a feature of considerable interest. The larval fin, however, still joins the various parts to each other and to the tail. The breast-fins are fan-shaped, and the eyes are large and bluish silvery. Generally speaking, the whiting has much black pigment on the postero-lateral region.

One about 12 mm. shows in spirit the dorsal and the anal fins outlined though not yet separated from each other, and the permanent rays are more distinct in them and in the caudal; minute ventrals are present, while the breast-fins form large mobile fans. Groups of black pigment-corpuscles are distributed along the base of the dorsal and the anal fins as well as over the brain, and a similar series occurs along the ventral median line of the abdomen. No barbel is noticeable. When a little longer (15 mm.), the species is distinguished from the young cod by a more abundant distribution of black pigment-specks along the sides of the body and on the fins, and by the greater length and diminished depth of the first anal fin. The median line of pigment still runs along the ventral surface of the abdomen. At 20 mm. the characters that separate it from the cod of the same size are better marked, *e.g.*, the distribution of dense blackish pigment along the base of the dorsal fins, and it soon spreads downward over the sides. The first anal fin assumes the character of the adult, and a minute papilla on the chin indicates a barbel. Between the stage just mentioned and a length of 28 mm. a decided change in the dense dorsal pigment takes place, viz., a tendency to form separate groups or touches (fig. 35). This feature is also seen to a slight extent in the young cod, and besides the dorsal series a few bars occur at the base of the tail. The fish is also now minutely flecked, all over the head, sides, snout,

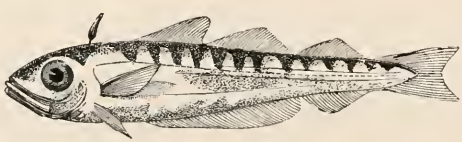


Fig. 35. Young Whiting with serrated dorsal pigment-band, and parasitic young *Caligus*.

and fins with black pigment, and its general outline approaches that of the adult. It is at once distinguished from the young cod by the shortness of the snout, irrespective of the features already pointed out, by the coloration, and by the shape of the first anal fin.

The authors of the *Scandinavian Fishes*[1] follow the opinion of Prof. Sars that the fry of the whiting seek the shelter of jelly-fishes, and feed on the crustaceans which live in the latter as parasites or which adhere to their tentacles, whence fishermen draw the conclusion in Sweden that the whiting is generated in the jelly-fishes and reared by them. There is no reason to suppose, in this country at least, that any such general habit prevails. Instead of looking for the young whiting inshore, as the authors mention, it is necessary to go to the offshore.

The differentiation of the two species, viz. the cod and the whiting, is very marked, in spirit, at the length of 34 mm. In the whiting the median dorsal fin is less abruptly elevated than in the cod, and the first anal differs widely, its elongation in the former being probably connected with the abbreviation of the abdomen. The body of the whiting is more plump and neatly rounded than in the cod, which is flatter and has generally a more prominent abdomen. The pigment-specks closely cover the sides of the body in the whiting, as well as the membranous webs of the dorsal fins, and are continued on the head. The pigment at the base of the caudal rays is more distinct in the whiting, and the lancet-like caudal termination of the body is longer in this species. The muscle-plates are coarser in the cod, and the surface has little of the dappled silvery sheen of the whiting. The chromatophores are larger in the cod, and are grouped in blotches over the surface, with intermediate pale patches, and the shoulder and the head have much less pigment than in the whiting. Both the breast- and ventral fins of the cod are shorter than those of the whiting. The snout in the latter is shorter and broader as well as deeper, and the short sub-mental papilla is in contrast with the long barbel of the cod of the same length. The whiting would appear to attain a plump body and finished outline sooner than the cod.

[1] p. 491.

The foregoing stages are very abundant in July in the deep water off the Isle of May and the mouth of the Forth, but they also appear west of Inchkeith in the latter estuary. They are indeed more characteristic of the former region, as far as present observations go, than of the shallow water of the open bays such as St Andrews, though on reaching a somewhat larger size they are quite common in the latter expanse. Thus the very great numbers that are procured by the mid-water net 25—30 miles S.E. of the Isle of May in July is in contrast with anything in inshore waters. They range, in a single haul of the net, from 9 to 58 mm., comparatively few, however, being at either extreme. Both they and the cod in these early stages are infested by a crustacean parasite (*Caligus*), which adheres to various parts of the head and body, just as another crustacean in a larval stage (*Anceus*) tenaciously attacks the young flounders in tidal harbours and inshore grounds.

At 2 inches in length the pigment has increased and the ventral fins have elongated beyond the vent.

The barbel is still distinct and appears to persist in some up to the stage represented by a length of $3\frac{1}{2}$ inches, though later it disappears, the adults having no trace of it. This is an interesting instance of an organ, which has been given up and done away with by the adult, persisting in the young stages.

As regards the habitat of the developing whiting we have already seen that there is reason to believe that it spawns on somewhat similar areas to the cod and haddock, though the pelagic eggs of the whiting are rather more abundant in the inner stations of the Forth, a fact which agrees with Dr Fulton's observations on the distribution of spawning adults. The young larval forms seem to swim about actively in the surface-water, and on assuming the post-larval stage the majority appear to adopt the same habits as the haddock and keep to the mid-water offshore, but on reaching the young stage (3 to 6 inches in length) they frequent the inshore waters and estuaries. They are also procured at some distance from land, being frequently caught in the mid-water net in the deeper water. It is rare, however, to find a whiting so small as $1\frac{5}{8}$ inches amongst the multitudes of gadoids (cod and green cod) that seek the tangle-forests on the rocks at low water. Only one example has been obtained.

As they increase in size great shoals are formed in the offing, though a few small ones are almost always found in inshore waters. Occasionally, *e.g.* in the Forth, indeed their number is so great as to be a hindrance, no less than 3000 having been captured in a single haul of a small trawl.

We have seen that in July the same haul of the mid-water net in the *Garland* gave on the 11th July in deep water offshore, specimens ranging from 9 to 58 mm. During the same month individual specimens of 55 mm. in groups of two, or three, and others of 80 mm., these sizes occurring separately, are captured by the mid-water net in the inshore waters. From their retreats in the offshore waters, therefore, it is probable that the young whiting pass to the inshore waters when between 50 and 80 mm. or thereabout whether the stage be reached in July or in August. This is the more likely as on the 9th August the same net used on board the *Garland* in the Moray Frith, under the care of Mr H. C. Williamson, secured a series ranging from 22 to 65 mm. These likewise had not yet sought the inshore area.

The question, in relation to those from 55 to 80 mm. in length and captured in inshore water ranging from 5 to 15 fathoms, arises, are they the fishes of the season, that is, were they hatched in April, or are they late examples of last year's series; hatched perhaps in June or July? Seeing that they differ so little from the largest in the swarms of young fishes undoubtedly pertaining to this season on the 11th of July, it is reasonable to conclude that they are the fishes of the season. Very considerable variation in size of the various groups of whiting is permitted by the extension of the spawning-period over a considerable interval. Moreover, no evidence has hitherto been available of the occurrence of very small whitings in numbers during the three first months of the year, which specimens might justly be relegated to the previous season's spawning. The hiatus in this respect is pronounced. We thus have in July a series ranging from 9 mm. to 80 mm.

or $\frac{2}{5}$ inch to $2\frac{3}{4}$ inches, all of which seem to belong to the season's brood, the largest of which under these circumstances are not more than 5 months old. This points to a very rapid rate of growth.

This variability in size is as characteristic of August, for in deep water, S. E. of the Isle of May, some small specimens only 12 mm. in length were obtained so late as the 31st; while on the 9th multitudes of whiting from 22 to 68 mm. occurred. Others, caught in fewer numbers, for so active a fish readily avoids the conspicuous mid-water net, range from 87 to 112 mm. or about $3\frac{1}{2}$ to $4\frac{1}{2}$ inches.

In September multitudes of whiting from 65 to 97 mm. or about $2\frac{3}{4}$ to $3\frac{3}{4}$ inches appear in the inshore waters, the larger and in some cases older examples pushing ahead of their neighbours into the estuaries of rivers as, *e.g.*, the Eden and the Forth, where they are occasionally captured by various nets in enormous numbers. Thus in the case related by Dr Fulton[1] more than 3000 were taken in the Forth in one haul of a small trawl (18 feet). In the Eden such forms range from 125 to 135 mm. or about 5 to $5\frac{1}{2}$ inches. The growth of these fishes seems to be remarkably rapid during the latter part of July, in August and the following month or two. Smaller specimens, however, are occasionally caught in the tow-nets, especially offshore, as usual with most fishes. Thus whiting of an inch to 27 mm. in length occur so late as the 22nd of September. In October, again, one of only 45 mm. was obtained inshore (St Andrews Bay). The authors of the *Scandinavian Fishes* state that they make their way to the inshore water only in October, and when 10 and 12 cm. long (4 inches). They keep such haunts, indeed, till spring, when they return to deep water.

In November the smaller specimens are from $3\frac{1}{2}$ to $5\frac{3}{4}$ inches, some exceeding the latter; while in December they are from 5 to 6 inches; such forms in both months being sometimes procured by the liners.

Mr Cunningham[2], reporting on Mr Holt's specimens of

[1] *8th S. F. B. Rept.* p. 175.

[2] *J. M. B. Assoc.* 1891–92. p. 358.

small fishes, observes that those measuring 4—$7\frac{1}{2}$ inches in January, may be divided into two groups, viz., those from 4 to $5\frac{7}{9}$ inches which had evidently been hatched the preceding April, and secondly those from 6 to $7\frac{1}{2}$ inches, about which he is somewhat doubtful, though he puts them down at 11 months. When, however, he comes to a fish $8\frac{1}{4}$ inches on February 20th he thinks the limit has been reached and he estimates it as two years old. But, according to what is shown above, if a whiting can reach $5\frac{3}{4}$ inches (or a little more) in November, especially in northern waters, it is by no means impossible for it to reach $8\frac{3}{4}$ inches the following February. The whiting is a remarkably predaceous fish, and the rapidity of growth towards the end of autumn favours the views here given. It is a saleable fish in its second year, and some imagine it is also capable of reproduction.

Young cod, green cod, and whiting from 8 inches to 1 foot long range the shores and follow up the tide into the harbours, and are known collectively as 'podleys.' There is however no difficulty in at once identifying the separate species comprised under this local title.

The average length, at which sexual maturity is reached, is about 8 inches, and the females, according to Dr Fulton, appear to be in a considerable majority (211 to 100), and they are usually slightly larger in size than the males.

THE POUTASSOU. (*Gadus poutassou*, Risso.)

The spawning season of this species probably occurs at the beginning of the year, according to the Scandinavian authors[1]. It is chiefly a southern and western fish, and probably in its adult condition frequents deeper water than its congeners.

Couch mentions that multitudes of young specimens about 5 inches long occurred off the English coast in July. Messrs Holt and Calderwood[2] narrate that on the 10th July, 1890, whilst the trawl was down at 175 fathoms, 34 miles from Achill Head, a large shoal of young poutassou was observed at the

[1] *Op. cit.* p. 514.

[2] *Sc. Trans. R. Dub. Soc.* v., *Ser.* II. p. 430, 1895.

surface darting actively about, and they were easily captured by a large tow-net. The mate, who saw them first, thought they were being chased by a large squid; but this was not seen by either Mr Green, Prof. Haddon or Mr Holt. The latter was of opinion that they had not come from any considerable depth but were at or near the surface. In length they ranged between $5\frac{1}{2}$ and 6 inches, and in the fresh condition the dorsum was of a dark greenish grey and the sides silvery. They were feeding on copepods and other pelagic forms. Unless the spawning-period is earlier than that of most gadoids such forms could hardly reach 5 inches in July. One of 15 inches mentioned by Couch in May was probably in its second or third year. Holt and Calderwood further observe "while, as Dr Günther remarks, the fish habitually lives in somewhat deeper water than its congeners, it seems probable that in its immature condition it is to a great extent pelagic and migratory."

The Green Cod. (*Gadus virens*, L.)

This fish, which is also known as the saithe and coal-fish, very closely approaches the cod both in size, habits and structure, and it is not therefore surprising to find that its life-history and larval forms have the same close resemblance.

The breeding-season is said to commence in January and probably continues through February, March and April. Parnell[1] observes that the spawn is deposited in the early part of the spring, and the fry are seen in June, 2 inches in length. Couch gives the same spawning-season, and mentions that the young are caught off the rocks in Scotland. Day writes—in Cornwall they spawn in spring. Other authorities place the spawning-period in spring, and Brook gives December to April. In the Cattegat it spawns at the end of March and beginning of April; whereas, in Massachusetts Bay, Earll found the spawning-season to be November and December. The ripe eggs were procured and examined in April 1892[2]. The females, as in the case of the cod and pollack, become greatly distended by the

[1] *Fishes of the Forth.*

[2] W. C. M. 10*th S. F. B. Report*, p. 287.

ripe eggs, which are very numerous, being estimated by Earll in one of 23½ lbs., as about 4,000,000.

The ovary of the coal-fish, like that of the wolf-fish, is peculiar in having very thick walls, in which are found circular and longitudinal muscles. Most of the gadoid fishes have ovaries with rather delicate walls.

The egg of the green cod has a diameter of ·0445 inch (1·161 mm.), so that it is, on an average, smaller than that of the cod and comes very near the size of the egg of the whiting; this and the fact that both are typical gadoid eggs, with no oil-globule, has no doubt caused many of the eggs of the former in their early stages to be classified with those of the latter. Moreover the resemblance of the later stages to those of the cod may partly account for the fact that little has been known till recently concerning the life-history of this species, in spite of its abundance in the adult state upon both the east and the west coasts. At some parts of the latter, indeed, as at Gairloch, the saithe is caught in immense numbers, and the facts about its early development were gleaned from eggs obtained from that area[1].

Eggs fertilized in the middle of February were hatched in about 12 days. They are very transparent and all the organs are clearly discernible throughout the period of incubation. By the 5th or 6th day the embryo has developed black pigment which, viewed ventrally, appears to be arranged in two lateral rows, with a few spots in the median region behind the eyes. The distribution of the chromatophores appears however to vary very much, and in some specimens they are found scattered over the whole surface of the embryo, as in a slightly later stage. On the 8th day the black pigment has increased; the ear-capsules are ovoid, but afterwards assume the usual spherical shape. A few chromatophores invade the yolk-sac, which has a wavy, oleaginous aspect. In some the oily material collects into a small globule on one side, a variation which shows the very slight distinction really existing between the eggs with oil-globules and those without. On the 9th day the appearance of the egg is seen in Plate III, fig. 8.

[1] W. C. M. 12*th S. F. B. Report*, p. 218.

On hatching, the larvæ (Plate X, fig. 4) float about helplessly with the yolk-sac uppermost. The fact that the pigment is slight and scattered distinguishes the larval green cod from the same stage in the cod, and the entire absence of yellow pigment in this and the later periods of incubation separates this form from the whiting.

About the 6th day after hatching, the chromatophores show a tendency to group themselves into dorsal and ventral masses, simulating, to some extent, the arrangement met with in the larval cod. There are also conspicuous groups of stellate black spots upon the back of the head, over the abdomen, and over the pectoral fins. The eyes have small black specks and are silvery.

Fig. 5, Plate X, is a larval green cod of eight days, showing the distribution of pigment above referred to and also the embryonic rays in the tail-fin; at the age of 14 days little more advance is made except in diminution of the yolk, the surface of the sac enveloping which now presents a distinct reticulation, and the more general scattering of black spots, which however still appear in a ventral view to lie in two longitudinal lines.

The green cod therefore, as surmised before identification, closely resembles the cod in its development.

The post-larval stages are still in need of investigation; they are probably very similar to those of the cod, but perhaps are more darkly pigmented. Fig. 6, Plate X, represents a post-larval fish of about $\frac{1}{3}$ inch in length, which is probably a young green cod. The belly is brightly coloured by crustacean food, the eyes are bluish-silvery, and larger in proportion than those of the cod, probably because the snout and the lower jaw are shorter in the green cod. Black pigment is found on the head and the belly. The increase and prominence of this black pigment is probably diagnostic of the later stages, but little of these is at present known, though figs. 7 and 8 (Plate X) in our opinion represent an older stage after the fins are differentiated.

The young green cod of about $1\frac{1}{8}$ inch are found in great abundance in the tidal rock-pools of St Andrews Bay in May and June, apparently preceding the young cod in their arrival. In Bohuslän, again, it is said they are 60 mm. long before appearing on the shores in July[1].

These two species may be readily distinguished, for the young green cod have larger eyes, blunter and shorter snouts and shorter lower jaws, and it is further discriminated by the shape of the first anal fin, by a deep green hue over the general surface, and by much more abundant and evenly distributed black pigment on the body and fins. It may also have yellow spots on the dorsal and anal fins, and the breast-fins may have two broad arches of pigment, as in the gurnard and other forms.

In July the same series is found as in May and June, viz., from $1\frac{1}{2}$ inch upwards to about $2\frac{1}{4}$ inches, which is increased to 3 inches by early October. Some occur in July even as small as $\frac{11}{16}$ to $\frac{7}{8}$ inch in St Andrews Bay. A series from the west coast of Ireland in July extend from $1\frac{3}{8}$ to $2\frac{3}{4}$ inches, a little more advanced than those on the east coast of Scotland[2]. So far as we can conjecture from the known spawning-period these little fishes of 3 inches must be at least 5 months old (May to September inclusive) and may be more. This would indicate a rather slower rate of growth during the first season than in the case of young cod. Further observations, however, are required for certainty on this point.

In July and August are also found the young green cod of larger size and probably belonging to the second year. A paler and a darker variety occur, probably in direct relationship to the difference in environment (cf. Cod). They are abundant around all our rocky shores and harbours and are known locally as 'podleys' (see Whiting).

THE POLLACK. (*Gadus pollachius*, L.)

Though by no means an uncommon fish on both the eastern and the western shores, yet the majority of those captured in the various nets are unripe. Young fishes are more frequently

[1] *Scandinavian Fishes*, p. 503.

[2] *7th S. F. B. Report*, p. 307.

procured in the inshore waters on the east coast, the larger examples frequenting the deeper waters offshore.

Little was learned of its breeding until quite recently. Thus Parnell, in his *Fishes of the Forth*, states that it spawns in February, after which it remains out of condition till May. Buckland, on the authority of Mr Dunn, observes that it spawns in winter, and that the young are seen in April an inch long, and quite black. Couch thinks it spawns about the end of the year, and the young, of small size, are noticed in harbours and on the borders of shallow rocks, moving about with a slow motion, and readily taking a bait. Day gives the early part of the year as the spawning-period, and mentions that on the 28th May, 1881, he received some specimens, from $\frac{7}{10}$ths to an inch long, captured at the surface. No scales, or even ventral fins, according to this author, are visible until the fish has obtained $\frac{4}{5}$ths of an inch in length. Brook gives a wide range, on the evidence of the Fishery officers, beginning with December at the northern stations (Wick), and ending with April and May at the southern (Berwick). Möbius and Heincke are uncertain on the subject, but say it probably spawns toward the end of winter, an opinion shared by the authors of the *Scandinavian Fishes.*

Some years ago[1] a few remarks were made by one of us on the spawning-period of this species. On the first occasion, only preserved ova were forwarded by the able assistant-fishery officer at Lerwick, Mr Duthie, but the following season he sent a few fresh ova in sea-water; their condition, however, was unsatisfactory[2]. Since the foregoing remarks were published, Mr Holt obtained two ripe females in the spring of 1891 off the west coast of Ireland, and, though no male could be obtained, they were fertilized with the milt of a cod. He found their diameter to be 1·13 mm. in the unfertilised condition, a size they, for the most part, kept after formation of the perivitelline space, though extremes ranged

[1] W. C. M. 10*th Annual Report S. F. Board*, p. 288 (1892); and 11*th Annual Report*, p. 246 (1893).

[2] This energetic officer, however, lost no opportunity of filling up the gap in regard to this and other species requiring investigation.

from 1·10 to 1·16 mm. Three days later they exhibited a very translucent embryo, devoid of pigment, and with no free caudal region. He was unable to develop them further.

Mr Duthie with difficulty procured a few fertilized ova on the 2nd May, 1896, and forwarded them at once. Unfortunately they were delayed in transmission, probably by the dense mist, and they only reached the laboratory about 5 p.m. on the 6th, the majority having succumbed. They measured 1·1430 mm., a size agreeing with that of the green cod and with some that were sent in solution in 1893. The living eggs were not quite normal, and the exterior of the capsule was covered with *débris* in all. The blastopore had closed, and the tail was just commencing to extend beyond the yolk (Plate III, fig. 7). The optic vesicles were distinct, and the auditory vesicles were indicated by a minute clear ovoid area. Kupffer's vesicle was present. Moreover, a series of black chromatophores occurred on the head and along the sides of the body to the tail. The notochord appeared in the middle line, but the muscle-plates were indistinct though probably present. The yolk had considerably diminished. At the sides of the embryo were groups of minute granules, the result in all probability of the abnormal conditions.

Next day, that is on the 7th May, the fifth day after fertilization, the ova were unhealthy and the development irregular. The lenses were now visible, and a prominence indicated the heart. The otocysts had two otoliths. The notochord was cellular, and the segmental ducts had formed. Posteriorly several large vesicles were at the seat of Kupffer's, and the tail seemed to be deformed. The black pigment-corpuscles were stellate in front of the otocysts.

On the 8th May, one of the embryos had escaped from the capsule, the latter apparently being somewhat delicate; but whether this was due to the abnormal conditions, viz., the long journey and the great heat, is unknown. In this example the heart pulsated, and an opercular aperture appeared behind it. The otocysts had moved forward, the pectoral folds were more distinct, and the muscle-plates more numerous. The notochord was multicolumnar. Kupffer's vesicle had various accessory vesicles connected with it by protoplasm. The tail extended a little beyond the yolk, which (latter) had a few pale wrinkles in front, and its surface was dotted with minute granules. In certain views finely branched processes projected from a black pigment-speck on the body to the surface of the yolk, evidently uncoloured prolongations which afterwards developed pigment. The black chromatophores on the head and along the edges of the muscle-plates were distinct, and some were slightly branched, especially on the head. In lateral views the pectoral expansions were prominent. When placed in pure sea-water, after examination, the embryo and its yolk rose rapidly to the surface. On the same date, an embryo within the capsule was less advanced, and the heart presented no movement.

Twenty-four hours later (9th May) the extruded embryo still survived. Considerable diminution of the yolk had occurred, but a rupture of the sac had taken place posteriorly. The eyes were more clearly outlined, and pigment was developing in them, while the choroidal fissure was prominent. The otocysts were much larger and had a rim. The heart pulsated and had endocardial papillæ. The pericardial space was large. The pectoral fins showed a thickened rim of epiblast. Kupffer's vesicle was still present. The black chromatophores were distinct, though those of the embryo in the capsule were more branched. Both specimens perished at this stage.

The pollack (lythe), though by no means uncommon, has thus been a somewhat difficult fish to deal with in regard to its ova. From information sent by Mr Duthie, it appears to come inshore only after spawning, and is by no means rare in June, July, and August. It is an active form, and generally struggles so severely when hooked that it is brought up dead. Moreover, the egg-capsules seem to be easily affected by confinement.

While the eggs have thus seldom come under observation, the young forms from about an inch to nearly 1¾ inches are abundant amidst the shoals of cod and green cod off the rocks on various parts of the coast in July, and are caught with the hand-net in pools, while larger forms—ranging from the last-mentioned size to $3\frac{1}{8}$ inches—occur a little further from low-water mark in similar regions in September. In the second week of October they are about 4 inches, and readily take a hook baited with mussel. A series of young pollack caught off the west coast of Ireland in July ranged from $1\frac{5}{8}$ to $3\frac{5}{8}$ inches in length. These were larger than those found in the same month on the east coast of Scotland, a difference which is also to be noticed in the case of several other species, and is probably caused by a higher mean temperature in the former district.

In their earlier stages the young pollack are recognized by the great development of black pigment, the arch of the lateral line and the prominent mandible.

Mr Cunningham is of opinion that those caught in Plymouth Sound in June and July and from 12 to 15 inches in length are over two years old. If, as he states, the pollack spawns in that neighbourhood in February and March, such would be two years and four or five months old. It is possible, however, that a year might be deducted if the pollack grows at the same rate as its congeners.

THE NORWAY POUT. (*Gadus esmarkii*, Nilsson.)

Mr Holt[1] took a ripe female off the Aran Islands, west coast of Ireland, on the 8th April, 1891, the diameter of the eggs being ·98, the yolk clear, homogeneous and colourless.

Other eggs in Cleggan Bay in the same region were obtained at the surface, and as they agreed in size and aspect Mr Holt considered them identical. The larva, which emerged from these, measured 2·80 mm. and resembled that of the whiting. The mouth was open, and the caudal fin had embryonic rays. Black chromatophores occurred on the head, formed two rows on each side of the dorsum to a point slightly posterior to median where the two rows coalesced, and fell short of the caudal region. Yellow pigment was diffused over the head, dorsum, and neighbouring part of the somewhat narrow dorsal

[1] *Trans. Roy. Dub. Soc.* vol. 5, series 2, p. 54, 1893.

fin, over the ventral surface of the yolk-sac, and along the margin, behind the vent, of both body and fin, the latter like the dorsal being somewhat narrower than in the whiting.

This species is a rare form on the east coast of Scotland, but is more frequently met with on the west coast of Ireland. The peculiar gadoid elsewhere described by one of us[1] is probably this species, though it differs from the figure in the *Scandinavian Fishes* by the more marked curvature of the lateral line, by the shorter region between the tip of the snout and the first dorsal, by the slight hollow of the snout over the eye, and other features. On March 24th the ovaries were far advanced, the eggs ranging from ·3810 to 1·1430 mm., so that the spawning-period was near, probably at the end of April. Collett in Sweden found gravid forms in February; while in autumn young examples of 40 mm. occurred amongst sprats.

The Hake. (*Merluccius vulgaris*, L.)

It is peculiar that the egg of the hake has not yet been met with upon the eastern shores of Scotland, though the fish forms so important an element of the 'catch' of fishermen. Couch states that it spawns early in the year, but in the cold season of 1837 it did not finish till August. The fish, however, is not confined to our shores but ranges into the Baltic and the Mediterranean, as well as the opposite shores of the Atlantic, where the egg was alluded to and figured by Kingsley and Conn. The egg and larva have been described very briefly by Dr Raffaele, working at Naples. He mentions that ripe specimens occur in January, the eggs which came under his observation being however fertilized in May. In British waters the spawning-period appears to extend from January to July inclusive, Mr Cunningham having found one perfectly ripe on July 6th, while Mr Holt procured one with nearly ripe ovaries at the end of June on the west of Ireland. He gives the diameter as 1·35 mm. and the large oil-globule at ·30 mm.[2] The number of eggs in a large female is estimated by Hollberg

[1] 11*th Rept. S. F. B.* p. 241, Plate XI.

[2] Prof. Herdman recently found spawning Hake on April 5th south of the Calf of Man.

at 2,000,000, while Olsen gives 7,000,000. During this time the ripe adults are said to refuse all food and to take up their habitat at the bottom, so that they may then be freely caught in the trawls.

The Scandinavian authors[1] state that during the greater part of the year the hake lives alone, or follows the herring and mackerel in companies, but in the spawning-season it collects in fairly large shoals at the spawning-places. In the Cattegat the spawning-season is in the middle of July, and it is said annually to frequent the same area.

The egg (Plate III, fig. 4) is pelagic, and by no means large for the size of the fish, having a diameter of ·9 to 1·03 mm. This is a size closely similar to that of the poor-cod. A large oil-globule is present, and in this feature the hake resembles the ling and the rocklings, and differs on the other hand from the true gadoids, such as the cod, the haddock and the whiting.

Dr Raffaele succeeded in artificially fertilizing the eggs of this species in early May and he gives the duration of development in the egg as 60 to 70 hours. This is an extremely rapid course of events and is no doubt due to the small size of the eggs and to the high temperature of the water at Naples during that month.

The egg of the flounder hatches in about $5\frac{1}{2}$ days, at 8° C., a temperature which is about the mean for the month of May off our coast, and as the egg of the flounder is about the same in bulk as that of the hake, it is not unreasonable to assume that the egg of the latter would take about $5\frac{1}{2}$ to 7 days in these northern seas. The period of incubation of the flounder's egg is reduced to $3\frac{2}{3}$ days at a temperature of 12° C., and at the same rate of reduction a period of 70 hours would correspond with a temperature of 13° C. or 55° F., by no means a high temperature for the Mediterranean waters. The close agreement in size of the eggs of the hake, flounder and poor-cod will be readily observed in the Table of the sizes of the various eggs.

In Plate III, fig. 4, is seen the embryo stretching across the yolk in the egg. The black pigment is scattered over the yolk-sac in stellate spots and a few also appear upon the

[1] *Op. cit.* p. 518.

embryo. At a slightly later stage the pigment has increased and is more generally distributed, and the oil-globule, in particular, has a few black chromatophores.

The larva upon hatching (Plate X, fig. 9), is elongated and has a yolk-sac extended backwards, the somewhat large oil-globule being situated at the extreme posterior end of the yolk-sac, a feature which if constant would be diagnostic. The median fin is continuous and well-developed, and the vent, some distance behind the oil-globule, opens at this stage about half way towards the edge of the fin. The black pigment is abundant round the eyes, below the brain and above the visceral cavity, and forms two lateral transverse bands in the region of the tail. This arrangement resembles that found in some of the typical gadoids, the tail-bands recalling those of the cod, and the pigment at the front part of the body that of the haddock, and especially of the rocklings. Raffaele refers also to yellowish pigment scattered over the body but his plate is unfortunately not coloured. If we may take his lighter shading to indicate the yellow pigment, then, as is readily seen, its distribution is closely similar to that of the black: in his synoptic table he speaks of the oil-globule having black pigment above and yellow beneath. He does not state the order of appearance in the embryo of the two pigments and, on the whole, more details are much needed. Beyond this early stage, nothing is yet known of the development of the hake.

Mr Holt in the survey of the fishing grounds on the west coast of Ireland procured young examples $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long, in 80 fathoms in August, these being the young of the season. In March, examples of 6 and $7\frac{1}{2}$ inches were taken respectively at 115 and 40 fathoms, and two of 8 inches in 53 fathoms in May. The latter may be taken to represent the average growth during the first year. A specimen of 15 inches, again, was captured off Aberdeen on the 6th June, and presumably is in its second year. All these were taken in trawls. On the whole it would seem that the hake, like the haddock, keeps to the deep water in its early stages, roaming after prey nearer shore when attaining the length of the last-mentioned example (15 inches) and upwards.

Greater Fork-beard or Forked Hake.
(*Phycis blennoides*, Brünn.)

Nothing is at present known concerning the eggs of this species, though in all probability they will be found to be pelagic, and possibly, like the rockling, the hake and the ling—with an oil-globule. Risso observed that the females were full of roe towards the end of spring and during summer.

Young specimens of 30 to 35 mm. are of a silvery hue and mackerel-like colour, somewhat resembling the young of the rocklings. The 3 or 4 rays of the long ventral fins are united by a broad membrane with black pigment, as in the rockling and ling.

In March, one of 12 inches was obtained by Mr Bain, the able Fishery-officer of Peterhead, on the rocks near that town.

On the 16th of the same month in 1886, an example 13½ inches long was procured on the sands of St Andrews after a storm. The ventral fin was 3⅝ inches long and the barbel 1¼ inch. This and the preceding were probably in their second year.

So rare are young specimens on the Swedish and Norwegian coasts, that the authors of the *Scandinavian Fishes* are of opinion that "the true habitat of the Great Forked Beard does not lie in Scandinavia, and scarcely in British waters, but further south in the Mediterranean." In the latter "the young specimens lead a solitary life among the sea-weed in shallower water (in the littoral zone)"[1]. The size of the specimens mentioned above, however, irrespective of the condition of the ovaries in certain females, would appear to show that breeding takes place in the British area.

The Ling. (*Molua molva*, L.)

The spawning-period of this fish varies from April to June inclusive.

[1] *op. cit.* p. 543.

The egg of the ling (fig. 36, and Plate III, fig. 5), is of moderate size, varying in diameter between ·042 and ·043 of an inch (1·08 mm.). It belongs to the group of eggs which is distinguished by the oily nutriment in the yolk being collected together into one large globule or sphere which gives the egg a very distinctive appearance. An oil-globule also occurs in its fresh-water ally, the burbot.

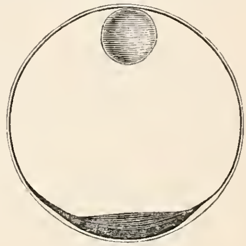


Fig. 36.

As has been already mentioned, to this group of pelagic eggs also belong those of the gurnard, rockling, brill, turbot and torsk, besides numerous demersal species, so that the presence of an oil-globule is not confined to any one group of fishes but may be present or absent in closely allied species[1].

This sphere of oily fluid seems in all cases to lie freely in the yolk below its protoplasmic coat (cf. Gurnard). The sphere itself may also be seen by-and-by to have a coat of protoplasm surrounding it. On moving the egg the oil-sphere may be made to travel through the yolk and even under the developing embryo, which in early stages rests like a cap upon one part of the yolk-surface. We have no reason to believe that eggs with oil-globules are more buoyant than those which have none: one would not expect that the fact of the oily matter being collected into one large sphere instead of being evenly distributed throughout the yolk would have any direct effect upon the buoyancy. The difference between an egg with an oil-globule and one without is therefore merely a difference in degree of segregation of the minute drops of oil scattered throughout the yolk. In the case of the ling, the oil-globule has usually a diameter of about $\frac{4}{15}$ths that of the egg, so that it is large in comparison with the latter.

The outer capsule of the egg is harder and more easily ruptured than that of the cod's egg, and hence the egg bursts rather than collapses under pressure.

The hatching occupies about 9 days for eggs which are laid

[1] Prof. Prince 'On oleaginous spheres in the yolk of Teleostean ova,' *Ann. Nat. Hist.* Aug. 1886.

towards the end of April[1]. Pigment first appears upon the larva at about the 7th day, in the shape of black stellate spots upon the back of the trunk. These spots increase and shortly after arrange themselves in two longitudinal rows, and a few spots appear on the yolk. About the middle of the 8th day, a number of fine greenish yellow pigment-spots appear, mostly on the ventral surface and on the marginal fin. The ling therefore, along with the whiting and the poor-cod, can readily be distinguished in the egg from the cod or haddock by the presence of coloured pigment before hatching.

The young larva on escaping measures about $\frac{1}{10}$th of an inch. Its appearance upon the second day after hatching is shown in Plate XI, fig. 4. The large and conspicuous oil-globule usually rests at the posterior border of the yolk. The yellow pigment is generally distributed, the black on the contrary being most conspicuous about the trunk and tail, and a few spots are seen scattered over the yolk-sac. These latter increase rapidly in size, and 2 days after this stage extend over the whole surface of the yolk. By that time (4 days after hatching) the yellow pigment has increased and the envelope of the oil-globule shows black chromatophores. The tail has now become very long in comparison with the rest of the body.

A week after hatching, the larval ling is very characteristic (Plate XI, fig. 5). About ·13 inch in length, it is thickly dotted over with oval yellow chromatophores, the black ones being finely branched and also conspicuous, though not so numerous as the former. They are grouped principally in dorsal and in ventral rows, with a mass collected at the posterior end of these rows just anterior to the tail, and another small mass at the back of the neck. The eye is of a metallic bluish colour. Amongst other structural features, we note that the vent has reached the outer edge of the marginal fin, and that there is a considerable space between the former and the posterior border of the yolk-sac. This is the latest stage reared in captivity and the next appears from the open sea, captured in the tow-nets at the end of August.

[1] For fertilized eggs of the ling one of us was indebted to a typical liner of the east coast, a race as industrious as daring, and as simple as contented.

This is a small post-larval form (Plate XI, fig. 6) about $\frac{1}{3}$ of an inch in length. Its gadoid affinities are at once shown by its large blue eyes, so like those of the whiting, and the two well-marked transverse black bars, extending across the trunk. The black pigment on the head is also very similar to that of the post-larval cod, as are the massive head and lower jaw. The peculiar structure of the paired fins, however, not only distinguishes this little fish from the gadoids but from any other known species. The pectorals have short fleshy bases which bear the fan-like expansions of the fin-rays. The ventrals are enormously elongated; at this stage it is seen that they are nearly half as long as the whole fish, the rays being of a yellow colour with black specks upon the membrane. This hypertrophy of the ventral fins is found to some extent in the rockling and tadpole-fish, fishes very closely allied to the ling. In each case it is strictly confined to the post-larval stages, neither the adult ling nor the adult rockling being conspicuous for large ventral fins. The large pectoral fins of the post-larval gurnard and bull-head present a feature somewhat analogous to this. The marginal fin is still continuous, and the tail is peculiar for an early development of the upper caudal rays.

Little post-larval ling of $\frac{1}{2}$ inch in length were caught in the 3rd week of July in the mid-water net at about 22 fathoms south-east of the Island of May. Except in size, these closely resembled the earlier stage described. At the end of August the ling had increased to a length of nearly 1 inch (Plate XI, fig. 7). A pale greenish tint is spread over the dorsal surface, and the black pigment is more diffused than formerly. The bands remain only on the dorsal half of the trunk, and there are a few changes, readily observed, in the arrangement of the black marks on the head. The ventrals are still very long, though not so elongated in proportion to the length of the body as in the former stage. It may also be noted that the dorsal, anal and caudal fins have assumed an appearance closely like that of the adult.

From this stage, at the end of the post-larval period, to the next described there is the gap which is so common in the history of many of the food-fishes. In the case of the ling, however, this gap is the more striking in that the young ling of about 3 inches in length[1] (see fig. 7, p. 32) presents a very marked contrast in many ways to the post-larval form one inch long. This is sufficiently seen by comparing the latter with figs. 6 and 7 on Plate XI. In the woodcut the little fish is boldly striped longitudinally with an olive-brown band, continuous from snout to tail, and above it is another lighter band of opaline lustre which is tinged with an edge of dull orange. A conspicuous black dot at the posterior end of each dorsal fin completes the remarkable coloration. Amongst structural features it is evident that the ventrals are greatly reduced in size proportionally and that a long barbel is present. This stage has been found in December and March represented by stragglers at rare intervals from deep water tossed on shore during storms; and it is well to note the great contrast in markings and colour which it presents to the young tesselated cod of about the same age. The age of this 3-inch stage is probably from $5\frac{1}{2}$ to 11 months, the former limit being perhaps under stated. In swimming in the tanks of the Laboratory it often carried the long barbel in front of it like a tentacle.

By the time the ling has grown to a length of 7 inches or thereabout, its appearance has undergone another complete transformation due to the fact that the longitudinal band has given way to a number of brown blotches with a golden lustre which run in dorsal and lateral rows more or less continuously from head to tail, and invade the second dorsal fin (see fig. 8, p. 33). The white streaks show here and there a bluish tinge with dots of black pigment over them. A golden tinge also occurs on the pectorals. The eyes (*irides*) are mottled olive, and the pupil black. The dorsum is pale olive with whitish streaks. The first and second dorsal fins are pale olive with whitish streaks and the black spot posteriorly. The tail has a russet-brown belt within the pale tip, which, like the extreme margin of the two dorsals and the ventral fins, is opaque white.

The ventral fins are pale but the posterior half or a little more has a brownish band with dark pigment at the tip. Three

[1] W. C. M. *3rd S.F.B. Report*, p. 62.

of the fin-rays have become free. They arise in front of the free portion of the pectoral, and the longest ray extends rather beyond the extreme tip of the latter. The barbel is very long and has greyish pigment. This stage up to 9 inches long frequents the rocky margins of the shore and is probably from 15 to 18 months old. Dr Fulton speaks of young ling as occurring in the Firth of Forth about September to a length of 12 inches. At the length of 16 inches Prof. Smitt, who gives a fine coloured figure[1], observes that the ground colour of the body is now reddish-brown above and milk-white below. The orange or pale olive colour of the dorsal line in the earlier stage has now extended over both dorsal fins, which are edged with yellowish white, and each with a black spot behind, the latter being more or less continued forward along the margin of the fin by a dark band below the white edge, which is either interrupted or broken up into small spots. The markings of the anal fin are similar, though the ground-colour resembles that of the belly, with a stronger tinge of grey. The caudal fin is of the ground-colour of the dorsal side, with the free edge broken up into spots. On this fin as well as on the sides of the body and the dorsal fins, traces of the opalescent stripe of the earlier stages appear in the form of irregular touches of violet and light blue. The pectorals are ashy-blue at the base, orange-yellow distally. The ventral fins are similar to the neighbouring surface. The barbel and the tip of the lower jaw are darker.

Later the young ling appear to migrate seawards and are caught usually far out at sea; the spots and bands of the younger examples gradually growing more and more faint, and in the adult the coloration is more or less uniform, the upper parts being greyish-brown or greenish, and the belly greyish-white, though variations occasionally occur.

Little is known with regard to the size of the ling when sexual maturity is reached, but data are to hand which show that this fish is the most prolific of all the food-fishes which have been investigated. F. Day quotes an instance of a ling of 100 lbs. in weight which was estimated to contain no less a number than 160,000,000 eggs!

[1] *Scand. Fishes*, pp. 528, 529, Pl. 26, f. 2.

Without relying too much upon this statement, we have instances, quoted by T. W. Fulton, which go to show that the ovaries of a ling may contain any number from 14,000,000 to 60,000,000 eggs. The magnitude of these figures can hardly be grasped by the human intellect, and the remarks made when treating of the fecundity of the cod apply with sevenfold force to the species under consideration.

The ling appears to spawn not nearer than 10 miles from the shore, and spawning females occur as far as 170 miles seawards.

As regards the rate of growth, the ling must be classed amongst the fishes whose growth is fairly rapid but perhaps not so fast as is the case with some other gadoids, *e.g.* the cod.

From data given by H. Williamson, we note that a 1-year-old ling averages about 6 to 8 inches in length or a little more, whilst at the end of another year, a length of from 14 to 16 inches at least may be attained, and nearly 30 inches is probably reached by the 3rd year; so that for the first 3 years the ling may be said to grow at the rate of about 8 inches per annum, or still more roughly—the greater part of an inch per month. The smallest mature female examined by T. W. Fulton was 18½ inches, so that it is probable that the ling, like the cod, attains sexual maturity at the 3rd year.

The life-history of no other fish can present a more absorbing and wonderful series of changes in colour and structure than that of the ling. The rapid transformation from the uniform yellow pigment to the black transverse bars, only to be replaced by the conspicuous brown band from eye to tail, and this in its turn giving way to the blotches and streaks of brown and pearly white, forms a puzzle which requires all the resources of mimicry and protection to enable the teleologist to solve, and this is quite impossible till an intimate knowledge of the whole environment of the species throughout its life is acquired.

Add to this the long ventrals disappearing before adolescence, and the enormous fecundity, with its attendant destruction of early stages, and one is compelled to admit how little is really known of the life and surroundings of these food-fishes.

THE ROCKLINGS. (*Onos mustela, O. cimbrius* and *O. tricirratus.*)

These little fishes have a very close relationship to the gadoids, and by some observers they have even been classified under the same genus, but it is usual now to place them together in one genus, known as *Onos* or *Motella.* They cannot strictly be termed food-fishes in that their diminutive size as a rule precludes their being utilised as food: nevertheless their importance in connection with fishery questions can hardly be over-estimated, for both in the young stages and later they form a considerable source of nourishment to the larger food-fishes, while their pelagic eggs are found throughout the greater part of the year.

At certain seasons of the year young rocklings are found in vast shoals frequenting the open seas, thus having a free-swimming or pelagic habitat: they are popularly known as 'mackerel-midges' and have been at various times described by naturalists as distinct species.

Disporting themselves in the surface waters, it may be amidst the gaily tinted jelly-fishes and salps, they are often "thrown on board vessels with the spray, or drawn into fishing-boats with the nets" (Day). The name mackerel-midge is derived from the fact that they are preyed upon by vast numbers of mackerel, and the movements of the latter in the spring are probably sometimes dependent upon the presence of shoals of 'midges.' Later, when the pelagic 'midges' have grown into 'rocklings' with, at any rate in some, a change of habit to shallow rocky shores, they still fulfil the function for which they seem to be destined by nature and serve as food to many of the large edible fishes. These facts being taken into consideration, a detailed knowledge of their life-history and habits becomes a desideratum.

The rocklings fall naturally into three 'forms' which probably have the morphological value of species, as three distinct eggs of rocklings are found on the east coast: the adults seem to differ mainly in the number of barbels or feelers which protrude from the region of the head. These appear to be tactile organs of the same physiological import as that of the cod and the haddock.

Onos mustela has five barbels and is usually known as the five-bearded rockling, *Onos cimbria* has four and *Onos tricirrata* has three; all have a single barbel on the lower jaw in a position corresponding to that of the cod, and the others are situated upon the snout.

The young rocklings appear in the nets from March onward, fresh series taking the place of the older forms which by and by, especially in the later months of the year, take to the bottom. It thus happens that up to the end of December specimens of 9 to 9·5 mm. occur. The smaller examples abound in April, May, June and July, an increase in size taking place in certain forms in each series in August, September and October.

At 3·9 mm. the abdomen posteriorly is covered with black chromatophores externally, and they extend downwards nearly to the vent. They also occur between and behind the great ventral fins, the aspect in this respect approaching that of the four-horned *Cottus*. Very delicate embryonic rays are present in the marginal fin, chiefly at the base; the caudal, however, having stronger rays of the same kind. A touch of black occurs on the dorsum over the posterior region of the abdomen, and another on the ventral edge in front of the tail. The ventral fins appear to have reached their maximum length in proportion to that of the fish, being little short of half the total length and of a deep black hue. Four of the rays are especially long, while the fleshy base of the fin is pale, and is a very little in front of the pectoral. At this stage the lower jaw still juts out considerably beyond the upper, especially when depressed.

At 4 mm. the body is short and thick, with the marginal fin continuous and with very fine embryonic rays. Stronger embryonic rays occur in the tail, radiating from the median notochord. A row of black pigment-specks runs along the ventral edge from the vent to the tail. Well-marked black chromatophores are present on the head and on the dorsum above the bases of the pectorals, and a few specks on the mandible inferiorly. The ventral fins are large, nearly a quarter the length of the body, and they are deeply pigmented throughout.

At 6 mm. (7th May) the marginal fin is still continuous, with embryonic rays, while true rays are developing in the tail above and below the notochord, which is slightly bent upwards and buttressed by a superior and inferior thickening (epiural and hypural). The pectoral fins are larger, and the ventrals are still of great length and deeply pigmented throughout (Plate XII, fig. 3). The top of the head and the dorsum over the pectoral fins have black chromatophores, and touches of the same pigment are present along the posterior region of the dorsum, and on the middle of the body occupying a corresponding line to the four or five chromatophores which alone remain on the ventral edge in front of the tail. Thus changes have already begun in the pigmentation. The abdomen is slightly silvery.

When 8 mm. long in spirit (23rd May) only one black chromatophore remains on the ventral edge in front of the tail, while the lateral pigment has increased, and the dorsal has extended forward to amalgamate with that above the pectorals. The abdomen and the sides—to within a short distance of the tail—are silvery. True rays exist in the dorsal and anal fins, but each is joined to the tail by the larval fin. The ventral fins are still very long. A little later (at 9·9 mm.), the black pigment of the ventral fins is confined to the distal region.

At 11 mm. (Plate XII, fig. 4, the example being 10 mm.) the pectorals still remain pale, though proportionally larger and with true rays. The ventrals have now pigment only on the tip, rather less than half the fins being black. The pigment has disappeared from the ventral edge of the body, and has increased along the dorsum, on the snout and on the cheeks. The general silvery hue is more conspicuous. No barbels are yet present. Such forms are known as "mackerel-midges." The black pigment has largely increased on the dorsum and sides at 14 mm., and also the silvery sheen. Touches of black likewise occur on the sides of the mandible ventrally. The history of the discovery of these midges and the determination of their true affinities is worth narrating.

Colonel Montagu, an acute and observant naturalist, as early as 1808, described in minute detail a small fish which he designated the Silvery Gade or *Gadus argenteolus.* It was caught off the shore of South Devonshire, and as the observation remained uncorroborated for many years by other British ichthyologists, the authenticity of the colonel's description, in spite of his well-merited reputation for accuracy, was called in question. No less than fifty-six years after, however, the shoemaker-naturalist, Thomas Edward, forwarded to Couch a specimen of a little fish for identification, and this turned out on examination to be no less than Montagu's midge or *Gadus argenteolus.* But, meanwhile, Couch had discovered the little mackerel-midge which was denominated *Couchia glauca* by Thompson. The two forms were evidently closely allied, but the main difference between them lay in the fact that Montagu's midge had two barbels upon the upper jaw, or three in all, whilst Couch's had four upon the upper jaw, or five in all.

Cuvier having already separated the rocklings from the true genus *Gadus* and having formed them into a genus to which he gave the name *Motella,* the midges evidently were more closely allied to the rocklings than the true gadoids, so a separate genus had to be made for them. To this genus the name of *Couchia* was given, so that Montagu's midge became known to scientific men as *Couchia argentata,* or perhaps preferably as commemorating its discoverer, *Couchia Montagui,* whilst the five-bearded form was *Couchia glauca.*

In 1865, the untiring energies of the Banff naturalist, Edward, resulted in the discovery of yet another midge which was fully described and named by Couch, as Edward's midge or *Couchia edwardii.* The distinctive title rests upon the number of the barbels, this most recent midge having three barbels on the upper jaw, or four in all. Couch remarks, "Compared with the latter (*C. montagui*) its shape is more slender, the pectoral fin rather more lengthened and pointed, the ventral fins longer and slender, the cilia on the back, along the edge of the membrane, more extended, apparently more numerous and very fine; barb on the lower jaw long."

There were thus made known to science three species of *Couchia* exactly corresponding to the three known rocklings, and although Couch remarked upon the 'analogy' of the two groups, it was left to Day and others to show that the genus *Couchia* included simply a series of young forms belonging to the genus *Onos* or *Motella* (rocklings).

THE FIVE-BEARDED ROCKLING. (*Onos mustela*, L.)

The development of the five-bearded rockling is best known. The ripe female is greatly distended and the eggs may be extruded by the slightest pressure; this is due to the fact that a great number of the eggs ripen at the same time, whereas in a number of allied species there is a gradual ripening and extrusion of the contents of the ovary. Dr Raffaele calls attention to the same peculiarity in the three-bearded species.

The spawning-period of the five-bearded rockling appears to extend from April to August (inclusive), as during these five months the egg is one of the commonest on the east coast: it is abundant in all parts except the region of Smith Bank, so that not only is the spawning-period one of the most prolonged, but the distribution is perhaps the most general of all the fishes which come under our notice. This extended distribution, in time and place, must be a valuable safeguard to the preservation of a species destined to be devoured by others.

The egg is pelagic, spherical, of small diameter (·028 inch, ·72 mm.), and is furnished with a yellowish oil-globule (·0033 inch, ·024 mm.). In this feature as in several characters of the post-larval stages the rockling gives evidence of its close genetic connection with the ling. The capsule of the egg 'is slightly corrugated and the entire yolk-surface presents a series of minute oleaginous particles.' During the month of May, the period of incubation at St Andrews[1] Laboratory extended over 10 days, whilst the late G. Brook[2] in his own sheltered laboratory at Huddersfield, and at a later season of

[1] McIntosh and Prince, pp. 677 and 832.

[2] G. Brook, *Journ. Lin. Soc.* p. 273.

the year found that the eggs hatched in half this time: the same observer gives the length of the newly hatched larvæ as ·087 inch.

The larva (Plate XII, fig. 1) upon its escape has little or no pigment in the eyes, but three touches of black occur on the body behind the vent. Black chromatophores also occur behind the eyes and otocysts, and along the sides of the body above the yolk. Before the mouth has opened in the larval rockling, the ventrals appear as minute buds below the pectorals, and are then distinguished by the black pigment, as the late G. Brook indicated.

Some days later (Plate XII, fig. 2) the larva presents a very characteristic appearance. We note the projecting lower jaw like that of the plaice, the large metallic-blue eyes and the definite patches of dark pigment. A small spot of stellate black pigment covers the brain, and a large mass of the same colour lies above the stomach and intestine, whilst two or three patches of a russet-brown tint mark out the trunk and tail; the marginal fin is broad and continuous and is devoid of pigment. There is a marked absence of all yellow coloration, a fact the more noticeable as the young ling is covered with little yellow specks. In a larval *Motella* described by Agassiz and Whitman, diffuse yellowish pigment is described as appearing on the 14th or 15th day, when the yolk has been absorbed.

In the five-bearded form here described, no yellow-pigmentation appears up to the absorption of the yolk, though the oil-globule still persists. The skin at this stage has a roughened surface, due to granular papillæ. The little fishes are somewhat delicate, perishing in captivity soon after this stage is reached, and we experience the usual break in continuity of the series of forms, which can only be filled up by long and careful search and study of the pelagic fry.

A form measuring 7·5 mm. from St Andrews Bay on the 17th June seems to belong to this species. The marginal fin is still continuous, but has true rays developing at its base, both in the dorsal and anal regions. True rays also occur in the caudal, in which the tip of the notochord is slightly bent up. In life the head was slightly olive, with black pigment; the abdomen silvery with reddish-brown contents. Blackish pigment occurred along the dorsum and sides—chiefly the former. The eyes were silvery bluish. The rays of the moderately elongated ventrals were dull yellowish, and thus in contrast with their general blackish dusting. The circulation was complete and in full activity. In contrast with the young four-bearded rockling of exactly the same length, the eye is brownish in the preparation instead of bluish-black and silvery, a condition, however, to which no weight need be attached. No pigment occurs on the body, but the ventral fins are brownish throughout, and much shorter than in the other species. The snout is less blunt and less heavy than in the four-bearded form, a feature partly due to its diminished diameter.

At 16·5 mm. a large barbel occurs at the tip of the mandible, and short processes at the anterior nostrils, as well as traces of the labial barbels. The pectoral fins are considerably elongated, though they have not reached as far back as the tips of the ventrals. The body is silvery with the exception of a small portion posteriorly, and with dark pigment at the dorsum. The tail is symmetrical, so that the bend of the notochord would seem to be temporary. A young parasite (*Caligus*) had fixed itself over the cardiac region.

At 24 mm. (Lochmaddy, August) the specific characters are evident, viz., the presence of the five barbels, the longest being that on the chin, and the last-developed the pair on the lips, the character of the head, and the greater depth of the region immediately in front of the caudal fin. Day states that the young of this form is brown with blue eyes, but not a few of the length just mentioned and larger—have the steel-blue of the dorsum and the silvery sides so characteristic of the four-bearded species. Perhaps, however, Dr Day alludes to a later stage, and variations may occur in regard to the assumption of the adult characters. The first ray of the dorsal is not much thickened in these bluish-silvery pelagic forms.

When 28·5 mm. long, on the 9th June, an example showed that at every stage variation occurs, since the labial barbels were just indicated and no more. The dorsum was not so deeply pigmented as in some, but the whole fish was silvery.

The filament of the first dorsal was long. The ventrals were still elongated, though proportionally shorter than in the early stages. They appear to be about $\frac{1}{7}$th the length of the body, and with black pigment at the tip.

One at 30 mm. in August had so far altered its habit as to have been found amongst muddy sand during a search for littoral annelids at Lochmaddy. Its more sober hue, deeper body, larger fins and less attenuated form at once distinguished it from the preceding stage. The dorsum was of a dull green dotted with black—merging inferiorly into the silvery lustre of the sides, though towards the tail the dull green again predominated. The cheeks behind the eyes were silvery dotted with black, the black specks, indeed, occurring over the entire body with the exception of the anterior part of the abdomen, which was silvery with a bluish-green iridescence. The irides were greenish-blue. In spirit the colour of the dorsum became russet-brown, and a faint brownish hue appeared on the sides. The pectoral fins were kept in rapid vibration, and the first dorsal had the usual active ciliary motion. The first ray of the latter had a probe-point. The head had now assumed its characteristic proportions. The barbels were longer. The ventral fins were still long, while the tactile extremities of the four anterior rays, especially the first and the long second (both being separate at the tip), were better developed, probably in connection with the change of habit.

A series of pelagic specimens captured between the 6th and 27th of October, show that in this species the dark dorsum and silvery sides are characters pertaining to pelagic life, and, moreover, that some pursue this habit longer than others, or at least attain a considerably larger size before assuming the condition just noted in that of 30 mm. from Lochmaddy.

The smallest of these range from 9·5 to 19 mm., but though they appear to agree with this species in pelagic dress, yet there may be a doubt. Not so with one of 25 mm. on the same date and in the same locality, viz., October 9th in the Moray Frith. The dark bluish-green dorsum and the silvery sides are as in the other species, but the depth in front of the tail, and the small labial barbels—together with the condition of the first ray of the anterior dorsal, place the identity beyond question. Similar characters are present in an example of 28 mm. captured in the same region on October 6th, though the first ray of the anterior dorsal is more slender. At 32 and 34 mm. in the same Frith on the 23rd and 26th of October, all the characters are better indicated, such as the proportional size of the head and the eye, the somewhat thick and slightly probe-pointed first ray of the anterior dorsal, which projects beyond the rest, the barbels and the depth in front of the caudal fin. The steel-grey of the dorsum and the silvery sides are well-marked, but the latter (sides), with the exception of the belly, are minutely dotted with black points so as to have a granular appearance. The ventrals are often injured at the tip, and young parasitic crustaceans (*Caligus*) cling to these and other parts, *e.g.* the cheeks. Lastly, one of no less than 40 mm. comes like several of the latter, from the surface, though from a different locality, viz., near Inchkeith. The colours agree with the foregoing, and the granular black pigment of the sides has now invaded the first half of the posterior dorsal fin. A similar example, 39 mm. long, comes from the stomach of a cod in August. It is thus apparent that other questions than size determine the change of habit and colour in this species.

Of those which present the change just mentioned, two were obtained amongst the rocks on the 26th July, and measured respectively 35 and 42 mm. All trace of the silvery hue has gone, and the entire body, as well as the second dorsal fin, is minutely dotted with black chromatophores, those on the abdomen both laterally and ventrally being distinctly larger. The first ray of the anterior dorsal still shows a slight probe-point, and the ventral fins are injured.

Another of 44 mm., also procured amongst the rocks in October, presents a silvery belly and more or less silvery sides—with the usual brownish hue elsewhere, the sides but not the abdomen being very minutely dotted with black chromatophores. Considerable variations are, therefore, exhibited by the five-bearded rockling in this condition.

In January the young five-bearded rocklings of a brownish hue and of the following lengths are met with between tide-marks, viz., 37·5 mm., with silvery sides, minutely speckled with black; 40 mm., also silvery and with similar black specks; 43 mm. without silvery lustre, and with bold black specks all over the body and fins, while the filament of the first dorsal is long; 52 mm., without silvery lustre, and with black grains all over. All these are the young of the preceding year. It is possible also that one of 70 mm., with black specks over the head and body, as well as faintly on the fins, may be an early one of the same year as the foregoing. The two first rays of the ventrals are conspicuously tactile, the second being the longer. Six other rays are visible. In April, young rocklings $1\frac{3}{4}$ inch long are occasionally met with at the surface. One of 80 mm. in July (Guernsey) appears to be a continuation of the series. In August at St Andrews, the smaller specimens range from $1\frac{3}{8}$ to $4\frac{3}{4}$ inches; while at Lochmaddy the higher limit is 5 inches during the same month. The larger are probably in their second year. The same may be said of those at 103 mm. in February, and of 110 and 133 mm. in November. Those of $6\frac{1}{4}$ inches are somewhat older.

Mr Cunningham found that specimens 1 inch long on 21st May were $3\frac{1}{8}$ inches in August in the tanks of the Laboratory at Plymouth; while in May of the following year one had grown to a length of fully 5 inches. He does not, however, make clear the age of the examples measuring one inch.

Day observes that, at an early stage, the five-bearded rockling may be distinguished from the three-bearded by the presence in the former of dull yellowish rays in the dark ventral fins. When nearly an inch long by the five barbels, by the brownish hue of the back and trunk (not always present). The eyes are smaller, the space between them broader, and the barbels are longer; the first dorsal fin is also longer from before backwards.

One reference is here necessary. Cornish (1879) states, in speaking of the five-bearded rockling, "The nest wherein the spawn is deposited is invariably formed of the common coralline, *Corallina officinalis*, thrust into some cavity or crevice of a rock close to low-water mark."

This statement is directly at variance with the facts above stated concerning the pelagic habitat of the rockling's eggs, and as these were actually spawned by the captured females in St Andrews Laboratory we can only conclude that the eggs and nest described above were those of another shore-frequenting fish.

The Four-bearded Rockling. (*Onos cimbrius*, L.)

The eggs of this species have doubtless been frequently captured, but their exact identity still remains to be fixed. Whether, in view of Dr Raffaele's diagnosis of the egg of the three-bearded rockling as having a diameter of ·74 mm., the larger egg to be dealt with subsequently belongs to this form or not, future observations alone can show. At any rate three different forms of rocklings' eggs are met with in the tow-nets. The species is common in the deeper water of the Forth, on various fishing-banks and off the Isle of May, and its younger stages are probably confounded with those of the other two species. It is only when the characters are beyond doubt that it is at present separated from its allies.

When about 27 mm. long (October 30th), or slightly more than an inch, this species is readily distinguished from the five-bearded form of the same length by the more slender caudal region of the body, and the diminished depth just in front of the tail, by the smaller extent of the first dorsal, and its longer filament, by the larger barbel on the chin, and by the more distinctly mottled condition of the pigment along the dorsum. The presence of the characteristic barbels makes diagnosis certain, the median on the upper lip being the last to appear.

One of 38 mm. (November 2nd) showed a smaller median barbel on the lip than the preceding.

In April of the second year they probably attain a length of 40 mm. and upwards. One of the latter size was procured at the surface on Smith Bank, off Caithness, on the 9th of this month.

THE THREE-BEARDED ROCKLING. (*Onos tricirratus*, Brünn.)

Dr Raffaele gives a description of the development of a rockling from the egg, which he identifies with this species. He has examined the mature three-bearded form and finds the same phenomenon of simultaneous maturation of a great number of eggs as we noted in the five-bearded form. He states that the freshly extruded eggs have no colour in the oil-globule and that in many cases there are three or four globules which later unite into one. The egg captured in the surface-water of the Gulf of Naples corresponds with this in all features except that the colour of the oil-globule is yellow, 'like olive oil.' The egg occurs in abundance from November to January and is ·74 mm. in diameter, the oil-globule being ·218 mm. The egg of the five-bearded form (see above) is closely similar in size, but its oil-globule is considerably smaller; in fact, according to Raffaele's figures, that of the three-bearded species must be very large in comparison with the egg itself.

The black pigment makes its appearance early and is disposed regularly in a dorsal double row of round cells, two in each segment. On the fourth day, the pigment is principally confined to the dorsal part of the body-cavity and to two dorsal and ventral masses in the tail-region, a distribution not unlike that of its five-bearded ally. The embryonic fin shows no pigment, and the anus terminates half way to its edge. Further increase in the black pigment is observed in later stages. It will be noticed that although this description resembles that of the five-bearded larva yet the oil-globule of the latter is less than half the size, and the spawning-periods of the two differ considerably.

Mr Williamson procured one of 45 mm. in length at Magnavacca on the 21st February, so that the growth of this form would seem to approach that of the other species. At this stage the dorsum is dark bluish-black and the sides silvery, while the second dorsal, the anal and the caudal fins show traces of minute specks. The head is somewhat like that of the five-bearded form, but is readily distinguished by the barbels and the larger mouth. The first dorsal seems to be nearly as long as in the species just mentioned. With the appearance of the scales and the forsaking of a pelagic life, a kind of metamorphosis ensues in the rocklings.

An egg occurs in March at St Andrews which is probably that of a rockling, other than the five-bearded species. It has a diameter of ·032 inch or ·82 mm., being thus slightly larger than Raffaele's measurement of the egg of the three-bearded form. It has a distinct oil-globule and occasionally, in addition, another definite pale area, slightly refractive and apparently differentiated from the yolk, near the animal pole (Plate III, fig. 9.)

In manipulating the egg this oleaginous mass in some specimens moved under the embryo and kept the egg floating with the animal pole above, the reverse of the ordinary position. The yolk is minutely streaked with short wavy touches and is not perfectly transparent, but the streaks may be only superficial.

The embryo developes slowly, black pigment appearing very early, and forming a line of spots anteriorly on each side of the body, and a few chromatophores below the oil-globule—with the addition rather later of minute round black spots on the surface or margin of this body. The skin before hatching is vesicular. On extrusion from the egg (Plate XI, fig. 8) the larva floats with the ventral surface uppermost, and the oil-globule is at the posterior and inferior part of the yolk (in this feature closely resembling the figure given by Raffaele and referred to above). About the fourth day after hatching the black pigment becomes abundant, forming a broad lateral bar in front of the tail-region and a small patch slightly more forward (cf. the larval hake). By refracted light this pigment has a brownish tint. Later (Plate XI, fig. 9) there appear two distinct black pigment-bars behind the yolk-sac as in the five-bearded species, but in this case the posterior is much the larger as well as the first to make its appearance. On the head and sides of the body the pigment has increased greatly. A peculiar feature was noticed with regard to the circulation, in that the heart was very late in commencing its pulsatory movements, a fact possibly due to the severity of the weather at the time of observation. The larval fishes were more or less quiescent, floating near the surface of the still water and only occasionally gyrating; later, active swimming movements were indulged in.

It is difficult to say definitely whether these larvæ were those of the three-bearded or the four-bearded form. If we may accept Raffaele's account as applying with certainty to the three-bearded species, then the above probably may be taken as being early stages of *O. cimbria*, though the northern forms of the three-bearded may have a larger egg.

The two preceding accounts agree closely in many points, but differ essentially in other details, such as date of spawning, size of egg, and of oil-globule, and distribution of pigment.

The Lesser Fork-beard. (*Raniceps raninus*, L.)

Little is known with regard to the eggs of this species, and none have been seen in a ripe condition. In all probability the pelagic egg will possess an oil-globule.

Parnell gives April as the spawning-season, while according to R. Couch it is July. J. Couch observes, that in April the roe appeared to be at the beginning of its enlargement, and that the young ones are produced at no great distance from land. The authors of the *Scandinavian Fishes* are inclined to relegate the spawning-period to July. In Mr Thompson's example on October 8th the "ova were contained in two small lobes about an inch in length." Another, 10 inches long, examined on the 21st November at St Andrews showed the organs extremely small, in fact, rudimentary.

Young examples have been procured occasionally; thus Mr Newman found several of small size amongst sprats in London, and Dr Charles H. Gatty obtained another at Great Yarmouth. Mr Dunn has also taken small ones from the stomachs of other fishes. A. W. Malm[1], again, caught a young specimen 13 mm. long, on the 23rd July in Lunnevik, Bohuslän. It was entirely whitish, with the exception of the ventral fins, which were deep black, while blackish-brown pigment also appeared on the

[1] Goteborgs &c. Fauna, p. 499, 1877. Also in *Scandinavian Fishes*, p. 561.

head, the front part of the sides, and across the occipital region; still the typical form of the species was already developed.

The foregoing contains the chief information on the subject until on the 29th October, 1894, a very young specimen was procured by the *Garland* in the Moray Frith, between Coversea and Burghead, the total length being about 9 mm. The outline of the little fish is remarkably clavate, the anterior end rising somewhat abruptly upwards from the slender body, while the prominent vent with its anterior ridge along the ventral surface of the abdomen still further gives bulk to the region. This anterior enlarged part of the fish occupies 4 out of the 9 mm. The skin seems to have been distinctly pigmented, a large shield-shaped area of brownish-black chromatophores with the broad end in front occurring between and behind the eyes, with a few isolated specks behind. The cheeks below the eyes are also speckled with the same pigment. The sides of the body from the pectorals backward are minutely marked with blackish-brown pigment, which in the preparation does not reach the tail. On the ventral surface the pigment forms a V with the point forward in the hyoidean region, and the angle of the ventral fin on each side is marked by similar chromatophores.

The snout is comparatively blunt, and the black eyes are of moderate or even small size for so large a head in a post-larval fish. They look forward, outward and slightly downward. The nasal organ shows only a single large opening close in front of the angle of the eye. The mouth is large, and a tongue-like process of the hyoidean region projects forward, on its floor. The breadth of the lower jaw inferiorly is considerable, so that the little fish rests steadily on this surface. The vent occurs at the end of a ventral ridge.

The second dorsal fin, like that of the adult, begins a little behind a line prolonged upward from the base of the pectoral, and stretches almost to the tail. At this stage the fin-rays are present, though the fragmentary condition of many of these gives a degree of uncertainty as to the actual continuity of the two. All that can be said is that the broken caudal rays rise clear of the injured dorsal and anal rays as if a slight hiatus existed. The anal fin commences immediately behind the vent, and extends in the same way almost to the caudal. The pectorals have a large free fleshy base, and apparently form considerable fans, but as only one had a portion of its rays present, the actual condition is uncertain. The ventral fins spring from the lower surface considerably anterior to the pectorals, and have evidently been of great length. Thus in regard to their position at this stage they differ from certain gadoids in which a change forwards takes place during the growth of the fish. The six filmy rays, all of which, however, are imperfect, extend considerably beyond the vent, whereas in the adult the longest ray falls considerably short of it. Like the ling, rockling and other gadoids, the tadpole-fish has very long ventrals in its pelagic stage, and, as Malm states, the colour of these would also appear to be characteristic, viz. deep black. No trace of colour on these fins remained in the present example, which had been much damaged before preparation.

In all probability such a specimen, if the date be correct, would issue from an egg spawned in July or August, and its capture in the region mentioned would show that the young are found on the same ground as their parents, which are often caught in crab-pots inshore, or thrown on the beach after storms.

Of the other sizes known, one of 8½ inches was got at Portrush on the 5th of March, while at St Andrews those procured in February were respectively 9, 10, and 10½ inches, and that already referred to on the 21st November, 10 inches.

The Torsk or Tusk. (*Brosmius brosme*, Ascan.)

No visitor to Shetland can say that he has had experience of all the novelties that come before him unless he has eaten the excellent torsk, a gadoid fish so frequently met with at table in these interesting islands. While it is occasionally found all along the eastern and western parts of the coast of Scotland, it is in greatest abundance in the north, where it is highly esteemed as a food-fish. Like others it was supposed to come from deep water to the coast at the time of spawning, but nothing definite was known of its eggs until Dr Fulton examined the ovaries of two very fine specimens of about 15 lbs. weight, and measuring 34 inches in length. In one of these he found large clear eggs having a diameter of 1·4 to 1·32 mm., and he estimated the total number to range from 790,000 to more than 2 millions.

The first ripe eggs were obtained on the 27th April from the Bergen Bank by Mr Mackie, Assistant Fishery-Officer, Peterhead, and by Mr Duthie, holding the same position at Lerwick, from 20 to 40 miles off shore, but they were unfertilized and had been preserved before reaching the laboratory. Mr Duthie, however, shortly afterwards succeeded in fertilizing a fine series in Shetland and forwarded them alive to the St Andrews Marine Laboratory[1], where they arrived on the 25th May, or four days after fertilization. The milt is comparatively small, appearing in a male specimen of good size as a frilled riband only 2 to 3 inches in length.

The eggs are typically pelagic, floating freely in the water, and having a diameter of ·0525 inch (1·333 mm.), while the large oil-globule measured from ·009 to ·0105 inch (·228 to ·266 mm.). The latter is characterised by its pale reddish-brown hue under a lens, and its faint reddish colour by transmitted light (Plate III, fig. 11), and in some a series of minute fatty granules lie under the large globule. No pelagic egg presents a more distinctive hue, so that it can readily be recognized in any collection. Oil-globules render a pelagic egg more conspicuous, and the colour in this case is a marked feature. The capsule is remarkably tough and resistant, and the fresh egg can only be ruptured by the exercise of considerable force. The punctures of the capsule are unusually distinct, and moreover it is marked by faint lines or creases, so that it resembles that of the brill, lemon-dab and sail-fluke. The micropyle (aperture for fertilization) is like that of the haddock, the external opening, which is in the centre of a depression, being smaller than the internal.

As the eggs had reached the fourth day, the earliest stages were not observed. The blastopore was in the act of closing or had closed, and the eye-vesicles had formed, while a broad wing-like expansion extended along each side of the

[1] W. C. M. *Tenth An. Rept. S. F. B.* p. 288, Pl. XV, 1892.

body. Two days later a considerable portion of the tail was free from the yolk, the lenses, ear-capsules, and the heart, in which slight contractions were evident, had likewise appeared. Moreover a few simple specks of dark pigment were scattered over the tail. The embryo jerked head and tail. The eggs had now gone to the bottom of the vessel, probably from the difference in the specific gravity of the sea water.

On the seventh day, black pigment specks were studded along the body and on the head, some on the latter and near the lobate breast-fins being stellate (Plate III, fig 12). The heart had its open end to the left, and was in full action. Each ear-capsule had two otoliths. The tail was much elongated, and had a group of black chromatophores at the tip. The space between the embryo and the capsule was larger, probably from the absorption of the nutrient yolk.

A feature of interest was the appearance before hatching of a greenish hue by transmitted light on the head and the tip of the tail. The combination of pink and green in this species is noteworthy and unusual amongst pelagic ova. Some larvæ emerged on the 9th day, and measured about 4 mm. They are characterised by the large pinkish-brown oil-globule, which is generally fixed at the posterior border of the yolk (Plate XI, fig. 3). An interesting feature in some was the free condition of the oil-globule. On depressing the tail of the larva the globule glides forward to the middle of the yolk, and on elevating the head it mounts to the anterior border of the yolk. Nothing, indeed, could better illustrate the features formerly pointed out in regard to the movement of the oil-globule—in the gurnard; and in this instance the passage of the brightly coloured globule through the yolk (and not merely at the surface of the yolk) was easily followed. This free condition of the globule was probably abnormal, but it is worthy of note. The larval torsk is further distinguished by the presence of five conspicuous black bars, viz., one on the head and four on the body. The chromatophores on the head are somewhat irregularly scattered, though in the egg a front view shows that a more or less symmetrical series occurs over each eye. The first patch or bar of finely branched pigment-corpuscles on the trunk is placed rather behind the middle of the yolk, though a little variation exists, and it is rendered the more conspicuous as the black pigment of the region along the multicolumnar notochord is present beneath. The next patch lies on the muscle-plates behind the vent, the last is at the tip of the tail, while a less definite one is intermediate. Besides the greenish colour (by transmitted light, yellowish by reflected) on the head and tail, the same hue is visible on the yolk-sac. The gut ends towards the upper part of the marginal fin, but a lumen occurs just within the tip. The surface of the yolk-sac, the breast-fins, and the marginal fin, is minutely vesicular. A little black pigment appears in the eye. The larval torsk are healthy and active, and can be transmitted long distances in a limited supply of water.

The chief feature on the second day was the increase of the greenish-yellow hue on the under surface of the head, on the yolk-sac, and the tip of the tail, from the development of the cutaneous vesicles, formerly mentioned, and such makes a bold contrast with the pinkish oil-globule. The ramifications of the black chromatophores have everywhere increased, those at the tip of the tail presenting a radiate arrangement like fin-rays. The liver appears on the ventral border of the gut, and the termination of the latter has moved a little downwards and often contains a rounded mass. The breast-fins and ear-capsules are larger.

The changes next day were the projection of the cartilages of the lower jaw, the increase of pigment in the eyes, and the passage of the end of the gut with the urinary vesicle near the fin-margin. The yolk had considerably diminished, and the restless little fishes used the breast-fins in balancing themselves. On the fourth day the eyes showed a greenish silvery lustre, and vermiform movements in the gut were marked, as well as spasmodic jerks of the lower jaw. When the black pigment-corpuscles are placed against a dark background, they appear brownish, as in the cod, rockling and other forms.

The larvæ daily increased in activity, and were characterised by the rapid vibration of the breast-fins. About a week after hatching the mouth had broken through, the yolk was almost absorbed, and only a trace of the oil-globule remained. The gut had not yet opened posteriorly, though it was close to the fin-margin.

The later stages of the torsk have yet to be described, but the materials for this purpose are too few, probably because the young forms keep to the deep water. A single example, 10 inches long, exists in the University Museum. It was captured in February, and probably was about a year old.

The Sand-Eel Family. Ophidiidæ.

General Remarks on the Sand-Eels.

The two common sand-eels are very closely allied, and it requires a trained eye to at once distinguish between specimens of the same size. As this distinction was only comparatively lately understood it is not surprising that the young stages are not yet clearly diagnosed. They have an economic importance far out of proportion to their small size and their little-known appearance. In many parts, especially on the coast of Britain, the sand-eels are dug up from the sand between tide-marks and are sold for human consumption; indeed, we bear witness to the very delicate dish furnished by these little fishes. They are also used very successfully as bait, and it is known that they form a staple article of diet to cod, whiting, mackerel, salmon, and other important food-fishes. At Elie, for instance, on the shores of the Forth a regular fishing for them takes place in summer for bait.

This utility of the sand-eel as a source of food to the larger food-fishes is not confined to the adult, but the immense numbers of larval and post-larval 'fry' also form a great attraction. So much is this the case that an intimate knowledge of the life-history and habits of these fishes may at any time prove of practical utility in giving the key to the migrations of 'schools' of larger fishes (see also Rockling).

THE GREATER SAND-EEL. (*Ammodytes lanceolatus*, Lesauvage.)

This species has not come under such close examination as its smaller relative, for it is not found in such abundance on this coast. As in the case of the latter, there is some doubt as regards the exact limits of its spawning-period. Day observes that he found the ovaries considerably developed in August, and concludes that it spawns in autumn and winter. Möbius and Heincke fix the spawning-season of this species, according to Bloch, in May, and mention that Malm found a female with enlarged ova in June. In the summer of 1890 the sand-eels occurring at Elie were examined[1] and both males and females were found to be ripe.

The capsule of the nearly ripe ovarian eggs was found to be tough. Scattered throughout the yolk were a number of small greenish-yellow oil-globules (Plate III, figs. 16 and 17). The ripe eggs (Plate III, figs. 13 and 14), on the other hand, presented a single large oil-globule of the same tint, doubtless formed by the fusion of the smaller ones found in earlier stages. They adhere to any body with which they happen to come in contact. The larger ones measure ·762 mm. in diameter, the oil-globule being ·195 mm. The outer surface of the capsule is minutely areolar, and can be divided into an outer and an inner lamina. The micropyle is very distinctly marked as a deep pit surrounded by a series of radiate furrows. The eggs are probably deposited in June or July. As regards the occurrence of a winter or early spring spawning-period in addition to that in the summer, further data are required before speaking with certainty, but the comparison with the lesser sand-eel and its hosts of larvæ found in early March must be borne in mind.

As regards the early larval and post-larval stages nothing definite is yet known. None of the young forms captured at St Andrews show the deep greenish-yellow tint in the oil-globule, so that, unless considerable change ensues, in all probability they belong to the lesser sand-eel.

[1] W. C. M. *9th S. F. B. Rept.* p. 332, Pl. XIII.

Many of those captured at Elie were 12 and 13 inches long, and the food present in the stomach consisted in most cases of a single adult lesser sand-eel, which fitted neatly into the elongated stomach—head first.

THE LESSER SAND-EEL. (*Ammodytes tobianus*, L.)

The lesser sand-eel appears to be the more common form at St Andrews[1], and indeed all round the shores of Britain.

It occurs in great assemblages inshore. As regards the time of breeding there is considerable divergence of opinion. Day found the lesser sand-eel in August and September with the 'roe advanced'; and Couch fixes the end of December as the spawning-season; indeed from the tenor of his remarks it is possible that he had actually observed the shedding of the spawn during, as he says, 'about the shortest days of the year.' On the other hand numerous observers give the months of May and June as the spawning-season, which may also extend into July (Thompson). In St Andrews Bay the end of December and January appear to be the chief months for oviposition.

Small males, none of which exceeded 6 inches in length, were common, but no ripe females were dug out of the sand in their company in May during former years. The ovaries presented only minute transparent, granular ova with a large nucleus. Some, however, were considerably larger than others. The larger eggs had a granular yolk with many small oil-globules.

On the other hand, ripe forms in a free condition have been found in May; and in the beginning of July they were captured in numbers at Elie by sand-eel nets, and many ripe eggs were found in the sand on the bottom of the boats along with ripe milt—both of which had escaped from the adult fishes.

In drawing inferences from the known facts, we thus have one or two alternatives to accept: the first of these is that the lesser sand-eel spawns indiscriminately from December to May,

[1] *Vide* W. C. M. *9th Rept. S. F. B.* p. 331, Pl. XIII.

a spawning-period comprising 6 months of the year, or secondly that it spawns every 6 months, viz., about June and about December. Although one cannot be too careful in making conjectures upon these points, yet we shall see that there are facts with regard to the larval and post-larval forms which tend to corroborate the latter hypothesis—that the lesser sand-eel has two spawning-periods in a year.

The female, which is larger than the male, appears to carry, when ripe, about 10,000 to 30,000 ova. This, as we have already observed, is not a great fecundity for a fish with pelagic eggs, so that without further knowledge we might surmise that the sand-eel has demersal eggs. The ripe female bores its way rapidly through the loose sand below tide-mark, and whilst doing so, discharges its eggs into the surrounding medium. Couch remarks, 'It is in this retreat, concealed and sheltered with the sand of the shore, that this launce sheds its roe, the grains being scattered as it passes.' Each egg is covered with a glutinous secretion, which causes it to adhere to the surrounding sand, in which it is safely protected. Here we have an explanation of the fact that the egg of the sand-eel eluded capture in St Andrews Bay although diligently sought for by surface-nets, bottom-nets and dredges. In fact the details with regard to the eggs are derived, not from captured specimens but from ripe ovarian eggs artificially extracted from the female.

The ovarian egg of the lesser sand-eel has at first no special oil-globule, but by the time it is ripe a large and conspicuous pale oil-globule is present (Plate III, fig. 15).

When ripe in June and July the ovary (roe) is of a deep reddish hue, and the majority of the eggs may be ripe at a given time. The ripe egg appears to be of nearly the same size as that of the larger sand-eel, but its oil-globule has a dull golden or honey-colour (pinkish-orange by transmitted light), and thus differs materially from the greenish oil-globule of the larger sand-eel. Occasionally, as in other forms, a larger and a smaller oil-globule are present. The micropyle agrees in structure with that of the larger species, and the eggs in the same manner adhere to the surface of glass.

Those procured in the beginning of January and measuring between 6 and 7 inches were also fully ripe, the abdomen being distended in both males and females. In the dead examples the eggs measured ·8 mm. and the oil-globule ·2 mm. Moreover the colour of the egg was pale greyish and that of the oil-globule, in certain light, pale greenish. Whether this variation in colour was due to *post-mortem* changes was not clear.

In St Andrews Bay there are found every year at the beginning of March immense numbers of small larvæ, which occur in the bottom tow-nets. They have been figured and described by McIntosh and Prince as larva D, and later they have been definitely identified by the former as young sand-eels, and the slightly yellowish colour in the oil-globule leads us to infer that they are of the 'lesser' species. Fig. 6, Plate XII, gives a lateral view of one of these little larvæ. They are about $\frac{1}{5}$th inch (5 to 6 mm.) in length. The yolk is small—being nearly absorbed, but the pale oil-globule is still present, contained in a thick layer of protoplasm. The larva is elongated (Plate XII, fig. 5) with a vent at about $\frac{3}{5}$th of length from head to tail, and has a little dark pigment along the ventral edge. In some points it resembles the young gunnel but may be distinguished by the arrangement of the black pigment. At a little later stage than in fig. 6, a double ventral row of black spots is found along the abdomen, single behind the vent and in the region of the pectoral fins. The marginal fin is continuous, while the mandible protrudes in front of the head. There are small transparent pectoral fins and a little black pigment, consisting of a row of black spots below the abdomen and another row dorsal to the intestine.

Such then is the little larval sand-eel which occurs in immense quantities upon the sandy bottom, in the company of numbers of larval herrings, which are more elongated, besides differing in other points, and of young arrow-worms, animals which are also of an elongated outline. When we recollect the shape of the adult sand-loving sand-eel and of the lancelet we are inclined to believe that the elongated form of the young sand-eels and herrings is also probably a special adaptation. The suddenness of the appearance of these larvæ and their abundance, at once prompt us to ask the question—whence come they?

They are practically post-larval, the yolk having in most cases been absorbed (Plate XII, fig. 7), but they have barely completed their larval period. We know that the eggs are buried in the sand and therefore the quiet period of larval existence during which the embryo absorbs its reserve of yolk-nourishment and prepares itself for active pursuit of its prey is most probably also spent in or on the sand. The other alternative seems to be that of supposing that the young larvæ, retarded by their yolk-sacs, wriggle out of the sand, after hatching, and spend their larval period pelagically, or upon the bottom: in either case some at least of them would fall a prey to the surface- or bottom-nets, whereas such is not the case.

Some observers, quoted above, speak of the sand-eel as spawning in the winter, and we have direct evidence that it does so in the end of December and in January on the east coast of Scotland. If we take into consideration the retarding action of a low temperature the probabilities are that it is these winter eggs that give rise to the swarms in March.

If, as may be possible, the early larval period is spent in the sand, then the sand-eel during its embryonic and larval stages has a quiescent stage of development protected from its many rapacious foes, which pursue it with remorseless energy during all its future changes of habitat, till the greater number of the adults again take refuge in the same shelter. In all probability, however, it leaves the sand as soon as it is hatched. Moreover, many have the intestine of a greenish hue, probably from algoid substances.

The March sand-eels are continually reinforced by fresh consignments emerging from the sand, till the end of April, but contemporaneously with this a migration of the larger ones commences. At the average length of about 9 or 10 millimetres (about $\frac{1}{3}$ inch) the little fishes forsake the bottom, and are now found in the mid-water, being doubtless led thence in the pursuit of their food. The sand-eel has now the general appearance seen in Plate XII, fig. 8. The figure was drawn from a young sand-eel which was caught with a great number of its companions in the bottom-net, at the end of April. This stage represents the termination of the bottom-habitat and the commencement of the journey upwards through the mid-water to the surface. There is little change in the pigmentation from the previous figure. A row of brownish-black pigment-spots (about a dozen) run along the dorsal wall of the abdominal cavity, on either side of the intestine, and there are traces of a ventral row, continued onwards from the vent to the tail. The median fin is continuous, from the neck round the tail to the belly. The notochord may be seen to be deflected dorsally at its caudal termination and the lower fin-rays are conspicuous. The vent opens at a point three-fifths of the length from head to tail, and this feature forms the only really conspicuous distinction between the young sand-eel at this stage and the young herring of about the same length. We have no reason to believe that the sand-eel and the herring are genetically allied, but we shall see (cf. Herring) that the whole series of phenomena connected with spawning, larval migrations, etc. are closely alike, and it seems reasonable to seek in this the cause of the structural resemblance of the young stages.

Almost immediately after this stage the young sand-eels migrate through the mid-water upwards to the surface, till we find during April and May countless numbers of young sand-eels from 12 millimetres ($\frac{1}{2}$ inch) upwards sporting themselves in the surface-water. They seem to abound some miles out from the east coast, examples being obtained from off the Isle of May[1], Aberdeen, Montrose and Stonehaven. These little sand-eels are found in great numbers in the stomachs of food-fishes, and doubtless are very delicate morsels.

The young sand-eels in May are found in the surface-water in millions. There are in the St Andrews Laboratory four jars of these May post-larval forms, taken 15 miles off Aberdeen, Montrose, and Stonehaven, and their number may be estimated at about 50,000.

Thus the young sand-eel forms a very important supply of food to other fishes, both in its early post-larval stage, when

[1] *Vide* W. C. M. *Trawling Report*, 1884, p. 360.

it covers the sandy shallows with innumerable hosts, and later, in the surface-water, before assuming the adult habit[1].

It is instructive to compare the change of habitat of the growing plaice and that of the sand-eel. In the former, life is commenced in the surface-water, with its bright surroundings of sunlight, and as the embryo advances in its development it is drifted towards the shore. Here the little larva, set free from its prison, migrates gradually but surely to the bottom in shallow water. With increasing size a slow seaward journey is commenced, so that keeping the bottom, greater depths are reached. In the other case, the embryo embarks upon existence (in the winter-spawning) in fairly deep water, and embedded in the dark still sand. From this secure retreat the larval form emerges and with increased size it works its way upwards to the light and warmth, and eventually disports itself in the surface-water, a prey to many a foe.

Many remain in the surface-habitat, which has its drawbacks, as shown by the long line of pelagic organisms sometimes thrown up by a stormy sea upon the shore, whilst others (Plate XII, fig. 9) pursued and hunted everywhere, bury themselves in the sand, whence they are withdrawn by man to serve his purposes as food or bait.

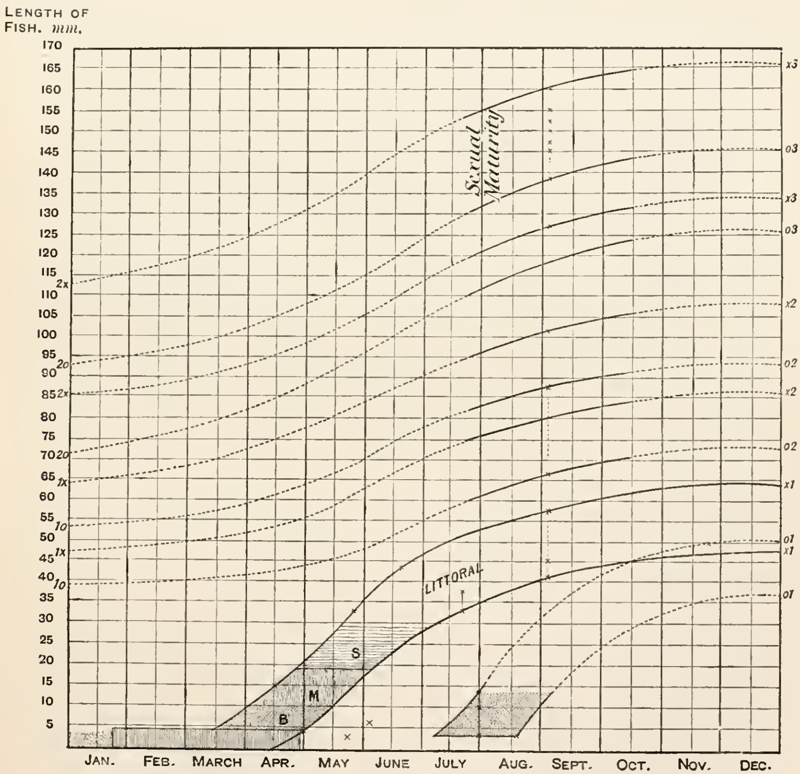
From the fact that very young sand-eels are found in multitudes at the surface in the offshore waters, it is clear that spawning in the sand also takes place there. Indeed, the ubiquitous habits of the species would render such probable. During the winter, besides, the eggs would be safer in deep water than in shallow water—even in the sand. The use of the sand-eel net in January in the estuary of the Eden gave only young forms of $2\frac{1}{2}$ inches, whereas the same net in summer and autumn captured numerous adults as well as intermediate stages. The adults were ripe in January, but whether in the sand or in the deeper water of the bay or neighbourhood was not ascertained.

The contrast in the life-history of two such common forms as the plaice and the sand-eel is thus fraught with meaning and is reflected in the form, shape, and colour of each at

[1] A. T. M. *Annals Nat. Hist.* October, 1895.

every stage of its eventful career. Of what nature is the strong instinct which causes the post-larval plaice to migrate downwards and the post-larval sand-eel to work its way upwards we cannot say; we do not even know the immediate factor through which the instinct works out its ends. A change in the specific gravity of the fish, a migration of the fish-food upwards or downwards, a sensitiveness to light, all suggest themselves as possibilities, but nothing more. At the length of six inches the lesser sand-eel becomes sexually mature; and the life-cycle is thus completed.

The early changes in habitat of the spring-larvæ are indicated graphically in the accompanying diagram.



B = bottom. M = mid-water. S = surface-water.

Note. In explanation of the above diagram, the area between 1 on left and 2 on right hand indicates the second year; while from 2 on left to 3 on right is the area of the third year.

In this, the larvæ from 4·5 mm. to 10 mm. are shown to inhabit the bottom (*B*), and after this length is attained to move upward through the mid-water (*M*) till at 15 to 20 mm. and over they are found at the surface (*S*). The curves have been determined by the measurement of preserved specimens so that the rate of growth is also indicated.

A further inspection of the diagram will show that in July and the earlier half of August there are found a number of little sand-eels from 4 to 12 mm. in length, living apparently near the bottom and evidently the progeny of the eggs deposited in May or June. Those caught are far fewer than in the March series, and it is probable that this is due to the eggs in the June spawning-period being laid in water too shallow for ordinary trawling operations and the swarms of larvæ remaining for some time in the same situation.

The March swarms are caught in greatest numbers at $\frac{3}{4}$ to 1 mile from shore and those in July in quite shallow water.

These facts probably find their explanation in different conditions of existence in the two periods of the year. In the calm summer months the eggs can be laid without risk in the sand of the shallows, where a high temperature favours development, whereas in the winter months the eggs, laid by the parent in the sand of the deeper water, avoid all risk from storms or great reduction of temperature. It may therefore be a simple case of the adaptation of an animal, guided by its instincts, to its changed surroundings. We may notice the same kind of phenomena in allied species, in which those spawning earlier in the year have a spawning-place further out to sea and those spawning late a spawning-place much nearer inshore, e.g. cod, haddock, and whiting.

We cannot trace these later swarms through the mid-water to the surface and we are unable therefore to say with certainty that they follow the same course as their predecessors of the spring. A little reflection will show that the latter pass their sojourn in the surface-water in the warmest summer months, whereas the approach of winter might render it an unfit habitation for the former. Under these circumstances it would not be surprising to find that the late summer brood do not travel to the offshore surface-water, but as it were, take a short cut in the life-cycle and assume a littoral habit at once. This subject is again referred to in the part upon the *Herring*, in which species it will be seen that the autumn larvæ do effect this short cut, eliminating the pelagic stage from their life-history.

It has been stated above that the lesser sand-eel probably has two spawning-periods in a year, and facts have been quoted in support of this statement, derived partly from the occurrence of larval forms and partly from the examination of adults. This result will not be invalidated by the occasional occurrence of isolated examples of spawning adults or of larvæ in the intervening period, for an extended spawning-habit is probably the precursor of the condition in which spawning is affected at two different seasons of the year. Experience teaches us that a 'spawning-period' is merely that duration of time in which the great majority of the individuals of a given species fulfil reproductive functions.

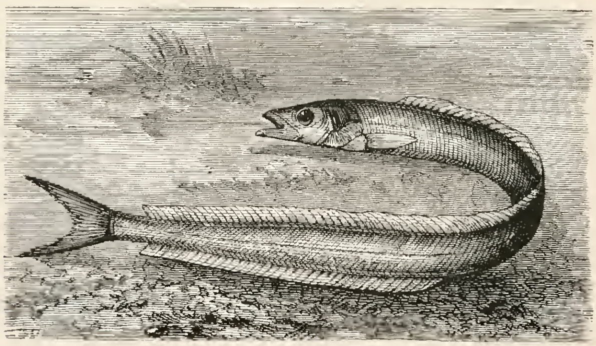
We may briefly summarise the life-history of the young sand-eel as follows:—

A sand-eel from an egg spawned in December or January, after a quiescent period imbedded in the sand, emerges upon the surface of the latter at a length of about 4 to 5 mm. At this stage the supply of yolk-material is generally exhausted, and the oil-globule only remains. The post-larval sand-eel keeps to the bottom till a length of about 10 mm. is reached. Living in company with it are found great numbers of larval and post-larval herrings, usually somewhat larger, and young arrow-worms (*Sagittæ*). There is a remarkable superficial resemblance, caused solely by the attenuated form of these three very diverse organisms, which is, of course, entirely absent in the adult stages. At a length of somewhat over 10 mm. the young sand-eel commences its migration upwards through the mid-water, and at this period its growth is very rapid. The average date for this change of habit will be seen to be about the end of April (see Diagram), sometimes earlier. By about the third week in May, or sometimes sooner, the surface will be reached, and in the three weeks' migration through the mid-water the little fish will have grown from 10—11 mm. to 17—18 mm., a very rapid rate of growth. The surface-period lasts from 17 mm. to about

30 mm., and extends from the third week in May till about the second week in June or thereabout, when the habitat of the adult is adopted. Here, again, in about three weeks, the young sand-eel grows from 17—18 mm. to about 30 mm. Sand-eels of larger sizes are caught at the surface almost everywhere, the universal distribution of this species being well known.

As regards the rate of growth of the lesser sand-eel, the double spawning-period makes it extremely difficult to gauge the age of each individual occurring throughout the year.

In June, specimens varying from 1 to $2\frac{1}{2}$ inches in length are found, and in July these appear to have reached $1\frac{1}{4}$ to $3\frac{1}{2}$ inches, whilst the smallest of these have increased to $1\frac{1}{2}$ in August.



Sand-eel at home.

CHAPTER IX.

Acanthini Pleuronectoidei.

The head is asymmetrical.

The Flounder Family. Pleuronectidæ.

The Halibut. (*Hippoglossus vulgaris*, Flem.)

The halibut is the largest of the flounder-tribe, and in its adult condition frequents the deep water, where it is usually caught by hook and line, though specimens also occur in the trawl. Stretching from the North Sea to both shores of America, the range of this large fish is most extensive, yet in modern times it is by no means frequent off the east coast of Scotland, the supplies coming from Shetland and the more distant grounds, especially Iceland and the Faröes. The Grimsby ships often bring 700 of them—ranging from over 6 feet to 18 inches—in a single trip.

Though thus well known in the market, the ripe eggs had up till 1892 escaped description. The spawning-period given by Parnell in his *Fishes of the Forth* is spring. J. Couch, again, does not refer to the subject, though R. Couch gives April as the spawning-period. Malm found one of 131 lbs. with "running" roe on the 26th of April, and ripe males (3¼ to 6½ lbs.) in spring. He estimated the number of eggs as about three millions and a half. Buckland quotes the period mentioned by Parnell, and adds that the roe is of a pale red colour and the eggs numerous—a remark, however, applicable to many unripe forms. Möbius and Heincke observe that the breeding-period occurs in spring. On the coast of Sweden the spawning-season is given as from February to the end of April; while in Iceland it is from June to August. On the shores of North America it lasts till September. The authors of the *Scandinavian Fishes* state that it approaches comparatively shallow places to spawn, perhaps even the mouths of rivers, but the grounds on which this assertion is made are not stated. Brook gives the period as from March to June; and Fulton found that the eggs were comparatively large even in February, but others were far from ripe in June, as indeed specimens forwarded by him in May and June clearly showed. No ripe examples had ever been seen by the men on the pontoon at Grimsby, and the examination of many hundreds in June, 1891, was not more successful. The determination of the spawning-period, indeed, even by fishery-officers stationed where hundreds are landed monthly, is full of uncertainty, though ovaries of 28 lbs. weight have been reported.

Mr Holt in the beginning of May, 1892, secured some fresh and apparently ripe eggs at Grimsby, their diameter ranging from 3·07 to 3·81 mm., and they were destitute of an oil-globule. The capsule had faint scribbled markings. They collapsed and burst very readily. Immediately after Mr Holt had kindly communicated this fact to one of us, Dr Fulton sent ripe eggs through Mr R. Mackie, Assistant Fishery-Officer, Peterhead, who removed them from a fish of 18—20 lbs. caught on the Bergen Bank 150 miles N.E. from Peterhead, and which had been three days on board.

The eggs, partly mature and partly immature, were preserved in a strong solution of picric acid, and had shrunk considerably. The perfectly ripe eggs appeared to be nearly circular, and had a diameter of 3·3 mm. Those less advanced, though fully 3 mm. in diameter, were more or less ovoid, as usual in unripe forms. Along with the foregoing were many unripe eggs having a nearly uniform diameter (1·9050 to 2·0574 mm.). In connection with these two sizes from the same fish, it is probable that most of the eggs, which in a given season are ripened and shed, increase to a size more or less uniform, but considerably smaller than the mature egg; and that subsequent increase to the ripe state takes place with more rapid strides than the previous growth, and in detachments. Such is the general impression, though no exact observations have been made.

Shortly afterwards[1] a consignment of apparently ripe though dead eggs was sent by Dr Fulton. They were the largest and perhaps the most beautiful of the eggs of flatfishes (Plate III, fig. 18). They had a diameter ranging from 3·4290 to 3·7619 mm., and before being immersed in sea-water, resembled a slightly milky mass of young *Salpæ*, or a quantity of boiled sago, their diameter, however, being considerably less than after immersion, viz. 3·0480 to 3·2766 mm. Many had been ruptured, and thus the fluid in the bottle was rendered milky from the yolk. It is probable that in perfection they are quite translucent. If, as they appeared to be, these eggs are pelagic, they are the largest known in our country; indeed Raffaele in the rich Bay of Naples found none over 3 mm. in diameter, though Wenckebach subsequently procured one of 4 mm.

The capsule of the egg is evidently thin—flapping to and fro with the movements of the fluid in which it was immersed. It by-and-by became tense by imbibition and exhibited slight elasticity, so that the egg was easily lifted by a pair of fine forceps and transferred from vessel to vessel. If the egg happened to fall on a plate of glass immediate rupture ensued. Proportionally therefore the capsule under these conditions is the thinnest yet met with in the group. It is marked by a series of fine creases or folds, which have a somewhat "coursed" or even stellate arrangement, like those of the lemon-dab or brill. The minute punctures occur all over the surface; the micropyle is in the form of a simple orifice of a slightly pinkish hue—like the large pores in the capsule of the torsk (a feature probably due to refraction). The yolk is quite transparent and homogeneous.

Next year, 1893, Mr Duthie, Assistant Fishery-Officer,

[1] W. C. M. 10*th S. F. B. Rept.* p. 286.

Lerwick, met with a ripe female of 22 lbs. on the 5th May, from Bergen Bank. In this case about $\frac{1}{2}$ a gallon of ripe eggs were obtained, but unfortunately the men had removed the roe from the fish the day before he met with them, and all attempts at fertilization failed. When these eggs reached the laboratory they were in excellent condition, and bore handling freely, showing that the eggs of the previous year had been softened. The diameter of these fresh eggs agreed with that given above, viz. from 3·0861 to 3·8 mm. In none of them was there any indication of a large space within the capsule (perivitelline space) such as occurs in the long rough dab, and as suggested by Mr Holt.

So far as Britain is concerned, therefore, ripe halibut have been met with chiefly towards the end of April and beginning of May. The ripe males, as in other forms, are considerably smaller than the females, some weighing only 14 lbs. or even less. Moreover the males seem to arrive at maturity somewhat earlier in the season than the females. Fries, Eckström and Sundeval consider that the spawning-season in Scandinavia (Bohuslän, &c.) lasts from the end of February to the end of April; while in Iceland it would appear to spawn from June to August. It thus, they say, nearly agrees with the spawning-season on the east coast of North America. Their view, however, that the halibut generally approaches comparatively shallow places to spawn is perhaps in need of corroboration, since in our country this has not been observed; nor have the very young stages of the halibut been found in the inshore grounds on either side of the North Sea.

The earliest known stage of the halibut is that figured by the able zoologist of the Danish Zoological Station, Dr Petersen, and first mentioned by Collet in his "Norges Fiske" (Plate XII, fig. 10). It was procured in Christiansand, and measured 32 mm. (about an inch and three-eighths). It had true rays in the median fins, but the breast-fins were quite larval (immature), so that the authors considered it probably had still to remain in the pelagic or free-swimming condition for some time, as also indicated by the position of the left eye, which has only just commenced to move forward and upward.

Petersen counted 104 rays in the dorsal fin, 88 in its anal, 22 in the caudal, but he points out that the number in the anal is somewhat greater than in the halibut, and in this and other characters agrees with the witch (*Pleuronectes cynoglossus*): yet the mouth is larger and the gill-cover has a row of spines, besides a few scattered ones, so that it differs from the flounders and thus approaches the brill and the turbot.

When they reach 12 inches in length by $3\frac{3}{4}$ inches across at the widest part they are occasionally met with in such shallow bays as that of St Andrews, thus showing that while, so far as known, their earlier stages are passed in deep water, they seek the inshore area and then like the plaice and turbot pass to the deep water in their adult condition. The general colour of these young forms was dull olive marbled with darker blotches, and also with reddish spots and touches which invaded the fins somewhat like the plaice. Such forms feed on young flat-fishes and shrimps.

The Long-Rough Dab. (*Drepanopsetta platessoides*, Fabr.)

During the Trawling Expeditions of 1884 an egg was frequently found in spring, especially during March and April, which was distinguished from all others by the large size of the perivitelline space,—that is, the space within the transparent capsule or zona in the early stages of the egg. It was mentioned in the Report on Trawling that these ova were one-third larger than the majority of the pelagic eggs, and resembled hydropic ova. The latter condition, however, was only apparent, and they were in all respects healthy, the advanced embryo with its yolk-sac lying in the centre of the transparent capsule. These eggs were widely distributed all along the eastern coast from the south of St Abbs Head to the Moray Frith, so that they evidently belonged to a common species. Though ripe long-rough dabs were seen in the dead condition in March 1884, and the eggs observed to be pelagic, yet, as this occurred during a violent storm, no opportunity was available of doing more than noting their condition, which, on issuing from the ovary, differs, as will by and by be shown, from their subsequent state. Thus the connection between them and the foregoing was not made out. Some specimens again seemed to have discharged all their eggs on the 21st March. Northern writers give the end of winter as the spawning-period, while Malm says the fishermen of Bohuslän observed that the roe ran in February and was spent by the month of March[1]. Every season (viz., in March, April and May) since 1884 these eggs have been brought in greater or less numbers to the Marine Laboratory and hatched. A figure of the same egg was also shown to one of us by Mr J. T. Cunningham in 1885, but he likewise had not ascertained the form to which it belonged, for in 1887[2] he observes that he had not been able to hatch it, and that no similar egg had been obtained from an adult fish. Further remarks on the egg and newly-hatched larva were made in the 'Pelagic Fauna of St Andrews Bay;'[3] the advanced embryo tending to the upper arch of the egg in floating, and presenting along the sides minute yellowish (chrome) and black chromatophores, which after hatching were still in most cases unbranched. In the *Researches*[4] the same egg was again alluded to, and the early post-larval fish figured. It 'presents three distinct yellowish bars behind the vent, another at the latter, and a line along the dorsum of the intestine, besides various touches of the same on the head and elsewhere. Stellate black chromatophores occur along with the yellow, and in the early condition are present on the yolk. The eyes soon assume a silvery aspect. The larval fish is active and comparatively large, resembling in certain respects the plaice. It is probably a pleuronectid.'

When surveying the fishing-grounds off the west coast of Ireland with Mr Green and Prof. Haddon in 1891, Mr Holt found that these eggs pertained to the long-rough dab, and thus their comparative abundance was readily explained. A similar relationship had been suspected at St Andrews, since

[1] *Scand. Fishes*, p. 425.

[2] *Trans. Roy. Soc. Edin.*, vol. xxxiii, p. 105, Pl. VII, fig. 2.

[3] W. C. M. *Seventh Annual Report Scottish Fishery Board*, p. 270, Pl. III, figs. 1–3. 1889.

[4] *Trans. Roy. Soc. Edin.*, xxxv, iii, p. 853, Pl. XVIII, fig. 2, Feb. 1890.

the ova of almost all the other pleuronectids except the halibut had been examined. These ova are especially abundant on the fishing-grounds to the east of the Island of May. So far as our experience goes, they chiefly abound in March, rarely a few occur in February, and in all probability, though nearly ripe, none are discharged before January. Off the west coast of Ireland Mr Holt found the adults spawning during the same months, viz., from March to the beginning of May.

It is remarkable that the obscurity surrounding the eggs of so common a fish should have remained so long. In a recent Scandinavian work[1] nothing more definite than hearsay evidence is afforded, though the statement of the fishermen of Bohuslän that the roe runs in February, and that the fish is spent by the month of March, is near the truth. Moreover, comparatively small specimens, both male and female, attain maturity.

By the energy of Dr Fulton, a large consignment of living specimens was forwarded to the St Andrews Laboratory in excellent condition in the spring of 1895, so that an opportunity was given for a re-examination of the development of this species—as described by one of us in the Fishery Board Report of that year[2]. The ripe females ranged from 7 to $13\frac{1}{4}$ inches, and all were distended with the enlarged ovaries. Moreover, as they lay on the dark bottom of the tank, the prominent ovarian region of the coloured surface was readily distinguishable as a broad pale pinkish streak. Some of the females were also marked with white touches, generally in pairs over the interspinous regions dorsally and ventrally,—very much in the position the dark touches hold in the pelagic post-larval forms. The males, on the other hand, were much smaller, ranging from $5\frac{1}{4}$ to $6\frac{3}{4}$ in. in total length, and presenting little or no distension,—a fact due to the minute size of the testes, which were wholly confined to the abdominal cavity, and were only about $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in length in a male of $6\frac{3}{4}$ inches. No larger male occurred in this collection, which consisted of nearly sixty specimens, so that the question may be raised as to

[1] *Scandinavian Fishes*, Fries, Ekström and Sundevall. 2nd Edit., 1893.
[2] W. C. M. 13*th Report*, *S. F. B.* p. 220.

the reasons for the limitation of the size of this sex and the small size of the male organs.

Most of the females were very ripe, and the slightest pressure caused the escape of a considerable quantity of ova, which fell in a mass into the water, and then slowly mixed with it. In the experiments made in the laboratory, the smallest trace of milt fertilized every egg in the vessels, which were about a foot across, so that the activity of the sperms was characteristic. The quantity of ripe ova discharged at a given time was quite as large in proportion as in the plaice, in the turbot, and in the flounder. Fishes in which the testes are small, as in the torsk, plaice, long rough dab, and sole, do not appear to differ much— in regard to the rapidity of issue of the ripe eggs—from those with large testes. The small size of the testes in the horse, compared with their large size in the porpoise, is another instance of the caution requisite in drawing conclusions on this head. At any rate, in regard to the fishes, the ascertained facts up to date do not seem to warrant strong statements on the subject. The ripe female sole in Scottish waters discharges a considerable number of eggs, and the same applies to the ripe lemon-dab. The quantity of ripe eggs which issues from a torsk is about as large in proportion as in a cod, yet the testes of the two differ much in size.

The egg of the long-rough dab, on issuing from the oviduct, is beautifully translucent (Pl. III, fig. 19), and measures from 1·0668 mm. to 1·1430 mm. The capsule (*zona radiata*) clings somewhat closely to the contained yolk, and is wrinkled all over—quite as much as in the lemon-dab. The perivitelline space is small, and thus differs from the condition as ordinarily seen in the tow-nets. As a rule, the yolk or egg-proper has a diameter of 1·0668 mm., while the capsule has a diameter of 1·1430 mm. When placed in sea-water, and whether fertilized or not, a gradual change takes place in the perivitelline space, so that next morning—that is, in 12 hours, the diameter of the capsule is from 1·7907 to 1·8669 mm.—probably by the imbibition of water, as in the case of desiccated eggs, while the diameter of the egg-proper in the centre remains nearly the same (Pl. III, fig. 20). This distention removes many of the wrinkles from the surface, but not all, since these are visible in almost every example up to the period of hatching. A very different condition prevails in certain viviparous fishes as described by Eingemann[1] in which a shrinking of the yolk occurred so as to form a breathing-chamber after leaving the ovarian follicle. Many of the eggs had groups of minute fatty granules dotted all over the yolk, as shown in the figure. Next day (22nd March), at 12.30, considerable progress had been made, the disc being in the mulberry-condition, the cells of the blastoderm being often prominent, and at 5.40 P.M. much more finely divided. The said minute granules of oil occur over the yolk, beneath the protoplasmic investment, and they appeared to be fewer next day, so that probably they were gradually used up in the progress of development. The minutely cellular disc presents an inward curvature at its edge, which is not quite regular—from the occurrence of minute projecting cells. The disc does not always occupy the centre of the yolk under examination. Occasionally a group of large oleaginous globules lies under the developing disc—not at the uppermost pole of the egg.

On the 24th, the embryo was outlined—with the optic enlargements. The blastopore in some was almost closed, and Kupffer's vesicle was represented by a few granules or minute vesicles. The notochord formed a pale streak extending forward to the middle of the trunk, and the margins of the body were faintly indicated.

Next day the blastopore had closed, and Kupffer's vesicle was large. Numerous muscle-plates had formed, and the notochord could be traced forwards almost to the head. On each side a delicate cellular border stretched backward outside the muscle-plates. The granules had now disappeared from the surface of the yolk.

On the 26th March, the embryo resembled Holt's fig. 58, Pl. VII[2], and traces of blackish pigment appeared along the body,—best seen by placing white paper beneath the specimens.

[1] *Vivip. Fishes. Bullet. U.S. Com.* 1892 (1894) p. 421.

[2] On the Eggs, larval and post-larval stages, of Teleosteans. *Trans. Roy. Soc. Dub.* v.

Besides, there are in some the pale precursors of the pigment-specks, which appear blackish by transmitted light. The notochord was visible throughout, the lenses in some were faintly indicated, and the otocysts appeared as elongated thickenings with a longitudinal slit, as in the green cod[1]. The heart was also distinct. The zona was thin, and readily ruptured even when the egg was carefully lifted.

The following day the blackish pigment formed dark bands, especially when viewed on a white surface, and the next day a faint yellowish tint was visible under a lens. The tail formed a blunt knob projecting beyond the yolk.

The yellowish hue was more distinct on the 30th March. On the head it was somewhat diffused, as the chromatophores had given off branches. The rows of rounded specks along the sides are only faintly tinted. Both yellow and black pigments were present. The latter (black) were very finely ramose on the dorsum of the snout and on the head, as well as behind the otocysts. Distinct muscular twitchings of the body occurred on this day.

On the 1st April, the embryo more than stretched across the egg (Pl. III, fig. 21); but in most the pigment-corpuscles remained simple. The heart was minutely papillose internally and trumpet-shaped. Slow contractions occurred at intervals. Most of the yolk was absorbed, and the alimentary canal formed a pale band in front. The otocysts sometimes differed in size. The day after, most of the yellow chromatophores in some were ramified, so that the colour was diffuse, but in others the pigment-specks remained circular. A few small black points were mingled amongst the yellow along the sides of the body. At this stage the yolk was quite free from pigment.

A few were hatched on 3rd April, and many next day. It is possible that the conditions as regards still water and low temperature may have considerably delayed hatching. A specimen removed from the capsule on the latter date (4th April, Pl. XII, fig. 11) differs in some respects from that figured by Holt, viz., a larva about half a day old, since the pigment is not definitely marked in his sketch. Moreover, the former

[1] *Twelfth Annual Report S. F. B.* Pt. III, p. 219, Pl. II, fig. 8.

presented no embryonic rays in the caudal; indeed, these did not appear for some time. Mr Holt's specimens therefore were probably more advanced at the period of hatching. No mouth is visible, and the œsophagus ends blindly in front. With the exception of those on the head, the yellow chromatophores are still rounded, though, as a rule, the pigment is branched at or shortly after hatching. In a lateral view, the yellow chromatophores are grouped chiefly at the dorsal and ventral margins of the muscle-plates, and on the rectum; the tip of the tail is devoid of them. Besides the yellow, very finely ramose black pigment-corpuscles occur on the head, and amongst the yellow along the body, but they are not easily seen after the yellow chromatophores become stellate, and in some specimens they are late in appearing. The upper part of the head is chiefly occupied by black pigment. A change must thus ensue before the pigment is grouped into bars, for it is somewhat general at this stage. The lumen of the gut has not entered the oblique portion of the rectum, and the pre-anal region of the marginal fin is small at this stage. A more advanced condition of the pigment is shown in a specimen (also removed from the capsule) on the 5th April. Both yellow and black chromatophores are finely branched. The variability in regard to the development of the pigment is further shown in the sketch of an example three days later, viz., 8th April, in which it is now grouped in bars,—that is to say, at certain parts the extension of the chromatophores is more pronounced than at others. Thus the head and the region of the body-proper have yellow and black pigment, the latter along the dorsal and ventral edges of the muscle-plates, with a special area at the rectum, and three bars behind it, that near the tip of the tail being mostly black, though a few yellow chromatophores are present. The eyes also have pigment-specks; the caudal shows embryonic rays. The yolk has considerably diminished. The otocysts are still elongated from before backward, but present a double outline from the differentiation of the capsule. The larvæ with a large amount of yolk swim with a wriggling movement.

They daily increased in size and activity, and the five groups of chromatophores became very distinct, viz., one on the body over the middle of the yolk, another at the rectum, two conspicuous bars behind—often broken up into a dorsal and a ventral band—and a small fifth near the tip of the tail. In the more advanced and more active larvæ, with the yolk much diminished, the pigment is more continuous. By reflected light, the colour of these larval forms is greenish-yellow, and thus it differs from the chrome-yellow of the younger stage. This change of hue appears to be due to the development of the black pigment amongst the yellow. The increase in the size of the pectorals in a few days became marked, and though usually carried more or less obliquely they were fan-shaped when viewed from above.

The chief changes till the 20th April were the deepening of the marginal fin, both dorsally and ventrally, the extension of the chromatophores—both yellow and black—of the two conspicuous bars behind the vent into the marginal fin, and the appearance of stellate black pigment-corpuscles along the ventral edge of the fin. Stellate black pigment also occurs on the abdomen, and the eyes are bright silvery. The yellow pigment still forms a line over the medulla and the first part of the cord. The caudal pigment-bar is chiefly black, only two or three yellow specks being present. The pectoral fins are larger and have rays; the upward slant of the mandible and the reduction of the yolk to a small round ball complete the features at this stage.

After the foregoing stage, in which this species and other pleuronectids resemble the larvæ of other fishes in shape, they begin to exhibit an increasing depth of body, disproportionate to their length[1]. In the earlier stages, when about 4·5 mm. in length, this flattening and depth of the body are diagnostic. Posteriorly an abrupt narrowing occurs, and the slender embryonic tail is continued as a tapering straight process bordered by the embryonic fin, which runs from the head dorsally round to the vent. The rays are longest at the base of the slender caudal process. Another feature of moment is the ventral projection of the abdomen, for it extends

[1] From the *Researches*, p. 836.

as a prominent swelling beyond the line of the body. As aids in diagnosing the mutilated young flounders of this stage are the proportionally smaller eyes than in the young round fishes, the structure of the tail, and the depression of the snout between the eyes.

The most prominent feature in the succeeding stage is the thrusting upward of the terminal caudal "whip" by the development beneath it of certain cartilaginous elements (hypural), and of the true fin-rays. The ventral margin is also finely dotted on each side with black pigment. The hypural cartilages so largely increase that they form a deep vertical boundary to the tail, the terminal (notochordal) process being bent upwards, and appearing, when viewed externally, as a slight filament. The depth of the body at the base of the tail has greatly increased. The left eye now shows a tendency to move forward and upward and a slight twisting of the frontal region is discernible, so that the symmetry of the head is no longer perfect. Small lateral bands indicate the ventral fins.

The examples referable to the long-rough dab were captured in the mid-water net at the end of August, and ranged from 5 to about 13 mm. Similar specimens, however, are likewise procured both in July and in September. Their distance from the inshore waters, and the depth at which they were found afford grounds for connecting them with this species, yet though the general outline is similar the mouth resembles that of the dab. At 11 mm. in length, the eyes are still lateral (Plate XII, fig. 12), and various black chromatophores occur along the lateral median line at the edge of the muscle-plates, on the head and on the jaws. Moreover, as Holt[1] pointed out, lines of black pigment follow the muscle-plates of the post-anal region ventral to the notochord. The most advanced of the series measured 13 or 14 mm. When one of 13 mm. was placed on its side a small part of the left eye was visible above the margin of the head (Plate XII, fig. 13); moreover, it was slightly anterior to the right eye, and its axis was directed somewhat forward. On the right side, four black pigment-spots were situated at the base of the interspinous bones, and the same

[1] *Op. cit.* p. 60.

number, besides specks on the body posteriorly, occurred along the ventral region. On the left side, only two were visible along the dorsal line and a few scattered specks along the ventral, as well as on the posterior part of the body.

During the Trawling Expeditions various small specimens of this species occurred from January to August, viz. from $1\frac{1}{8}$ in. to $3\frac{1}{4}$ in. and without any special differentiation of the sizes in the various months[1]. Holt[2] subsequently procured small forms in August off the West coast of Ireland, the smallest being 27 mm., roughly about 1 in., and the series ranging to 45 mm.; he considered them to be the young of the year. With these were a second series from 93 to 95 mm., that is, between 3 and 4 inches. Holt considered them to be from 15 to 16 months old; while specimens of 181 and 214 mm. from Aran in April, were probably about 2 years old; and one 300 mm. (12 inches) about 3 years and 3 months old.

The Turbot. (*Bothus maximus*, Will.)

The ripe eggs of this species were first procured on the 10th July, 1884, during the Trawling Expeditions, from a female of 12 lbs. (Buckland estimated their number at 14,000,000, in one of 23 lbs., whereas Collett in one of 775 mm. (= 31 in.) calculates their number to be 1,056,000.) Neither at that time, nor in 1892, when Mr Holt found another ripe female on the Pontoon at Grimsby, could a male be obtained. He subsequently, however, succeeded in hatching them, and gave the first accurate account[3] of the larval fishes, though none lived more than a few days after escaping from the egg. Recently, Dr Canu[4], who is carrying out fishery investigations for the French Government at the Marine Station of Boulogne-sur-Mer, has been able to fertilize the eggs, and has given a brief note of the development. The perseverance of Dr Fulton and the practical skill of Mr Harald Dannevig at the Dunbar Hatchery of the Fishery Board have at length made it possible to give a more

[1] *Op. cit.* p. 361. [2] *Ibid.* p. 68.

[3] *Jour. Mar. Biol. Assoc.* 1891–92, p. 399.

[4] *Ann. Station Aquicole*, Boulogne, 1893, p. 131.

complete account of the development of this species. It is remarkable that few, if any, eggs of the turbot are found in our inshore waters, either at the surface, in mid-water or at the bottom, indeed it is one of the eggs that has hitherto escaped capture in the tow-nets of the laboratory. This may be due either to its tendency to sink—after a time—to the lower regions of the water, or to the distance of the spawning-grounds. The spawning-season would seem to extend from the beginning of June to the end of July at least, and probably passes beyond both margins. The authors of the *Scandinavian Fishes* state that it spawns in May and June (*fide* Nilsson and Malm).

The ovarian egg (Plate III, fig. 22) approaching maturity is filled with rounded spherules of yolk which, as usual, disappear in the ripe condition (Plate III, fig. 23). The ripe egg has an average diameter of 1·0287 mm.[1], and the single oil-globule which it contains measures 0·21 mm. On extrusion, the healthy eggs are perfectly buoyant—floating at or near the surface of still water. In some instances, however, at Dunbar, many of the eggs went to the bottom, probably because changes had occurred by long retention in the ovaries. The capsule is very distinctly wrinkled—both in the fertilised and in the unfertilised condition—as in the lemon-dab. The oil-globule presents no special tint, and retains a nearly uniform diameter in all the specimens, as Holt has already noticed. When the eggs were in mass the latter observer was of opinion that the oil-globule gave a faint yellowish (ochre) hue to the whole. The eggs are sensitive in the early stages, and with difficulty bear a journey, especially in warm weather, and it would be well in such cases to delay transmission until the embryo has formed. Those fertilized at 6 a.m. on the 22nd June were in the multicelled condition at 6 p.m., but the disc showed certain peculiarities, the result of the journey by rail from Dunbar to St Andrews in glass vessels (thick earthenware jars being much better for transport), and the entire series perished before next morning.

Another series of eggs, fertilized on June 21st at 5 p.m.,

[1] Wenckebach says ·75 mm. *fide* Cunningham, but as Ehrenbaum observes, this is probably an error.

bore the journey and the heat more satisfactorily, and presented at the 24th hour, viz., about 5 p.m. on the 22nd, the germinal cavity and shield. As the embryo became outlined next day (23rd) a tendency to the formation of numerous large vesicles at the ordinary site of Kupffer's, as well as extending forward along the body in groups, was a conspicuous feature. How far this condition was due to the vicissitudes the eggs had encountered is an open question, but it was pronounced. On the 24th June, the embryo was distinctly outlined—with optic vesicles, lenses, cardiac thickening, and other features, while the large vesicles above-mentioned were fewer. Moreover, in some a series of chromatophores were thickly dotted along the trunk, and a few over the brain, but no colour was yet visible under a lens, though the embryo was indicated by a distinct opacity.

On the 25th, the eggs (Plate III, fig. 24) presented a slightly reddish hue under a lens. It was also interesting to note that the diameter of some of them had increased in the direction of the long axis of the embryo so that they were ovoid. The head and body were studded with rounded, reddish (ruby-red by transmitted light) chromatophores, some however, being only slightly tinted. They likewise extended over part of the yolk. The protoplasmic investment of the oil-globule had a few black specks.

Next day the pigment-corpuscles had a deeper ruby-red, and black chromatophores had also appeared. The pectoral expansions were distinct, the vesicles had vanished from the ventral aspect of the trunk, while the tail was longer and had a few black chromatophores near the tip. The black pigment at the oil-globule had increased. Only a few red and one or two black chromatophores were present on the minutely vesicular yolk-sac. The black corpuscles seemed to form a band along the edge of the body superiorly and inferiorly. On the 27th June, the colour under a lens was brick-red—from the branching of the red and black chromatophores. The eyes were somewhat darker, and the yolk had still further diminished.

Most of the eggs hatched about the sixth or seventh day, the same period being mentioned by Holt, the larval turbot between the first and second days having the aspect shown in Plate XIII, fig. 1, and it is about 2·2 mm. in length or a little more. The increase in the red pigment is characteristic, the body under a lens having a brick-red hue with black chromatophores scattered over the surface. The rounded reddish chromatophores of the embryo were now much branched on the head, trunk, two caudal bars and the rectal process, and some had appeared around the oil-globule and at the throat as well as in the cardiac region. The two brownish bars at the tail had a somewhat triangular or bluntly conical form, and extended from the trunk to the border of the marginal fin. A slight patch also occurred dorsally in the latter about midway between the caudal bar and the head. The finely ramified black chromatophores covered the entire region tinted reddish, so that only the middle of the yolk-sac was translucent, and even on this were a few much branched red corpuscles. The ventral surface of the yolk-sac, as well as other parts, had numerous black chromatophores. By transmitted light the coloured parts had a fine ruby-red hue. The eyes had a similar colour, a few dark touches also being present. The abundance of pigment obscured the ear-corpuscles and their two otoliths. Even at this stage the larval fishes darted about at intervals, after resting on the bottom, or floating with the yolk-sac uppermost and the tail downwards. In Holt's examples the oil-globule was ventral, but in ours it occupied a more or less posterior position.

After two days, the pigment in the eyes had increased, and they were slightly iridescent. The black chromatophores over the body were more abundant, while the bars behind the vent were broader, especially the superior, which almost touched the margin of the fin. The mouth was open, and the mandible protruded. The oil-globule adhered to the remnant of the yolk nearly in the middle of the abdomen, though it was slightly variable in position, in some having moved upward and backward with the diminishing yolk.

On the 1st of July, the larval turbot evinced greater activity —darting through the water at intervals, and again resting on the bottom. The increase of the black pigment rendered the body dusky brown. The two posterior bars had spread out, and finely ramified black pigment was evident in both. The mid-dorsal patch now touched the edge of the body and it also presented a few black chromatophores. The same brownish hue tinted the marginal ridge over the head and snout. The black pigment rendered both dorsal and ventral surfaces dark when viewed on edge; two long blackish bands occurring dorsally—separated by the brownish area in the mid-dorsal line. The skin was finely dotted with minute vesicles. The eyes had a greenish iridescent lustre. The marginal fin continued as a prominent border over the head to the tip of the snout. This fin was still proportionally broad, though the body had lengthened to fully 3·46 mm. No fin-rays were yet visible in the caudal expansion. Movements of the mandible and of the hyoidean apparatus occurred occasionally. The pectoral (breast) fins had considerably increased in size, and were used in balancing. The clavicular bar was also evident. The oil-globule was difficult to see, but, in some, it was found with the remnant of yolk near the lower border of the abdomen. A feature of moment in these larval turbot was their hardihood, for after exposure on a slide in a few drops of water for two hours, they became active when transferred to their vessel.

The yolk was entirely absorbed by the 3rd July, that is, about the seventh day. The marginal fin over the head had increased in depth, and the pigmentation had ramified outward in all directions at its inner border. The tail showed faint embryonic rays. Blood-vessels with pale blood were now observed, *e.g.* the sub-intestinal coursing upward in front of the rectum and passing towards the liver, the mandibular and the sub-notochordal trunk (aorta) which could be traced backward to the inferior line of pigment behind the posterior brown bars.

After the disappearance of the yolk, the turbot may be considered as having attained their early post-larval condition, and they swim through the water by rapid strokes of the tail and vibrations of the pectorals. In still water they often remain suspended with the head downwards, but there can be little doubt that, like the plaice observed by H. Dannevig, they would luxuriate with their heads directed to the current —in the constantly moving water either of the open sea or of the apparatus at Dunbar. The body of the little fish was dull reddish, more or less ruby-red by transmitted light, but by reflected light it had a dull ochreous or pale brownish hue (Plate XIII, fig. 2) finely marked with black. The outer margins of the two dorsal patches were pale, and the pigment immediately behind the prominent posterior bars was also pale, these lighter touches being very evident during the vigorous movements of the animals. The abdomen was deeply pigmented all over with black. The head and anterior region were conspicuous, both from the great depth at the opercular region, and the development of pigment on the abdomen, so that the aspect was somewhat like that of a tadpole. The eyes were greenish-silvery, the pectorals were large and fan-shaped, with reddish and black pigment at the base, the latter extending outward into the fin as long branching lines, which resembled very much the ramifications of rivers in a map. The angles of the mandible projected prominently downward, —as it were—enclosing the anterior hyoidean region in a deep furrow. The vent was now open.

Besides the movements above-noted, the little turbot occasionally swam at the surface on their sides, skimming along with rapidity, and moving the hyoidean region actively. They were extremely quick in observing the movements of the minute crustaceans and other forms in the vessel, and seemed to dart at them for food. No form hitherto observed at St Andrews appeared to be more hardy, or to undergo the vicissitudes of temperature and manipulation with greater impunity. There are grounds therefore for expressing the hope that they may yet be reared in great numbers from the post-larval to the adolescent and adult conditions in suitable enclosures.

Larval turbot are seldom caught in the tow-nets, though from a figure by Prof. Marion[1], they would appear to occur off Marseilles on the 2nd March.

Between the early post-larval stage shown in fig. 2, Plate XIII, and the later post-larval condition there is a gap, but it is slight, for Holt was fortunate in procuring at the surface in the North Sea a series of post-larval forms ranging from 5·50

[1] *Ann. Mus. Marseille*, IV, 1, Pl. 2, fig. 20.

up to 6·25 mm. They are deeply pigmented, with a short, obtuse snout, and an acute angle at the lower jaw. The tail is narrow and the belly prominent in the smallest example. The tail becomes deeper and the abdomen less projecting at 7 mm. One of the most interesting features is the presence of an armature of spines, to which one of us had previously drawn attention, best marked in specimens 10 to 15 mm. long, on the head, behind the eye, on the articular region of the lower jaw, and on the opercular region. These persist till they reach 25 mm., and Holt has even found traces of them in an example 175 mm. in length. An air-bladder is present. At 13·5 mm. the right eye shows above the ridge. Mr Cunningham, again, remarks that young brill swimming horizontally at the surface occur in the south in May and June, whereas turbot in this condition are later, viz. August and September.

Dr Petersen[1] also points out, after a spineless early stage, the presence of spines on the head of the pelagic turbot of 7 (Plate XIII, fig. 3) to 15 mm. long, particularly over the left eye, though also present on the right, on the operculum, beneath the lower jaw, and at the upper end of the clavicle. These, though disappearing, were still noticeable in one of 21 mm. Again in those of 7—8 mm. (Plate XIII, fig. 4) traces of true rays occur in all the median fins, and the notochord is boldly bent upward. In comparing it with a brill of the same size it is evident that the turbot is in advance of the brill in development.

When the young turbot (Plate XIII, figs. 5 and 6) reach the bottom, Petersen states that all the spines disappear, except the interocular cusp. The fins have the full number of rays, and the form is like that of the adult. At 33 mm. the scales and surface-spines (transformed scales) appear, but some specimens are larger before these are developed. Young specimens of the turbot and brill are distinguished, amongst other characters, by the number of rays in the dorsal and the anal fins. In the turbot, the rays of the dorsal range between 68 and 56; those

[1] *Danish Biol. Stat.* 1893, p. 131, Plates 1 and 2.

of the anal from 50 to 42; whereas, in the brill, the numbers are higher, viz. 80 to 70; and 60 to 54[1].

Dr Ehrenbaum[2] has also obtained specimens of similar size to Plate XIII, fig. 5, viz. from 10 to 12 mm., in July; and he gives a careful account of them. He mentions the horny processes at the end of the clavicle.

Off the east coast of Scotland pelagic specimens $\frac{13}{16}$ in. to $1\frac{1}{8}$ in. occur in July[3], and in August they increase in size and take to the bottom. Thus by aid of a net for capturing sand-eels a series ranging from 41 to 62 mm. were taken at the margin of the estuary of the Eden on the 7th of September. The size, however, is variable, for others reach only $1\frac{3}{4}$ in. on the 15th. Increasing in size they are caught 3 inches long, close inshore on sandy ground, by the same net worked from the land by aid of a boat in the middle of December. In February some are 6 inches, but others in April are only $5\frac{1}{4}$, while one on May 23rd only reached $2\frac{3}{8}$ in. The latter would seem to have been a very late example or to have been arrested in growth. As a rule, specimens of 6—8 inches occur in June, while in September many are captured on the sandy ground in 3—5 fathoms from $9\frac{1}{8}$ to $9\frac{1}{2}$ inches, the latter apparently representing the growth from the previous spawning-season, or during a period of about 15 months. Great irregularity prevails in the growth of this as of other fishes, and the rate of growth in captivity is an uncertain guide. Thus for instance at Concarneau[4] young turbot hatched in the aquarium in June had only reached a length of 2 to $2\frac{3}{8}$ inches the following April; while others hatched in April had grown to $5\frac{1}{2}$ and $7\frac{1}{2}$ inches. Smaller races of fishes are also to be met with on certain grounds.

A specimen 18 mm. long, with the right eye on the ridge, was taken on the 20th of June in Norway[5], and it was estimated as "at least a month old."

[1] Vide W. C. M. *Report*, *S. F. B.* 1892, and Dr Petersen.

[2] *Op. cit.* p. 287, Pl. VI, fig. 21, 1896.

[3] Vide *Trawling Report*, 1885, p. 360.

[4] *Fide* Cunningham, *J. M. B. Assoc.* 1891–92, p. 357, Extr. from *Bullet. Soc. Imp. Zoolog. d'Acclimat.* for 16th June, 1865.

[5] *Scand. Fishes*, p. 440.

Many years ago, a young turbot 25 mm. long, with both sides of its body coloured and an eye on each, was captured at the surface as it disported itself on edge amongst the *Salpæ* of the Western Isles in August[1]. It had a dull flesh-colour spotted with black chromatophores, which also appeared on the fins. The dorsal fin had about five dark bars. The right eye was slightly higher than the left, and the direction of the axes of the eyes was different. The opercular bones of both sides were armed with spines, and a prominent spine occurred at the angle of the mandible in a line with the posterior part of the orbit. The dorsal fin commenced rather behind the posterior part of the orbit, and a distinct crown of the head was observed between the eyes on looking from above. The ventral fins were minute, and behind them a deep notch, after which the anal fin commenced. The tail was inclined somewhat downwards and thus affected the symmetry of the fish.

After reaching a length of about 10 inches the turbot seeks the offshore waters, the deeper parts of which form its home and its breeding-grounds.

The smallest mature turbot seen by Fulton was 18 inches, and the largest 28 inches long. Cunningham conjectures the latter to be at least four years old.

To summarise,—the eggs of the turbot are as a rule shed in the offshore waters where the larval and post-larval stages are spent. The young turbot then, in many cases, seek the margin, or disport themselves at the surface, of the inshore waters; their youth is mostly spent in this area, but as they reach 10 or 11 inches they seek the deeper waters offshore.

This large and active fish presents certain difficulties in regard to voluntary spawning in confined areas, as for instance in the ponds at Dunbar. Hitherto it has refused either to shed milt or eggs without artificial aid, so that it is a much less successful form to experiment with than the plaice, which spawns freely. Moreover, in confinement the turbot is liable to ulcerations of the white surface, on the opercular region of the right side, and on each side at the tail. Such injuries are

[1] *Proceed. R. S. Edin.* 1865–66, p. 15; and Figures 5 and 6, Plate VI, Marine Invert. and Fishes, St Andrews.

probably due to friction against the bottom or sides of the pond, and even though the bottom was covered with sand the ulcers had a tendency to appear. In confinement, the adults are extremely fond of herrings and sand-eels just as they are when free.

When, however, the eggs are obtained and fertilized, no difficulty is found in hatching them, for the 'Dannevig'-apparatus at Dunbar causes constant and equable movement. Thus the tendency to sink—observed by Holt and others—is counteracted.

The Brill. (*Bothus rhombus*, L.)

Notwithstanding the comparative abundance of the brill off the shores of Britain, few opportunities for the examination of its eggs have occurred, and even now some points require re-investigation, since the eggs hatched at St Andrews were fertilized with the milt of the turbot. A close similitude, however, exists between the two species in regard to development. In all probability, like the turbot, the brill spawns only in deep water.

Amongst those who have written on the subject, Parnell, in his *Fishes of the Forth*, states that the brill spawns in spring: Malm found a ripe female on the 20th May on the coast of Bohuslän. Couch does not appear to have seen a ripe fish, and Day has no information of his own concerning its reproduction. Recently Raffaele gave some attention to the egg of this species at Naples. The floating egg was found in February and March, with a diameter of 1·33 mm., the oil-globule being 0·23 mm. He describes the brownish pigment of the embryo in the egg, and gives a figure of a larva with the yolk partially absorbed (fig. 18, tav. 4) which he doubtfully refers to the brill. The head of this larva is peculiar, the snout being pointed superiorly, and the oil-globule placed somewhat behind the centre of the yolk ventrally. The pale brown pigment with some darker specks is distributed generally over the body and yolk-sac, while a patch occurs in the marginal fin dorsally just behind the pectorals, and a broad bar dorsally and ventrally about midway between the vent and the tip of the tail, behind which the caudal region is translucent. In all these features it thus closely approaches its ally, the turbot.

Mr Holt in 1890 procured a ripe female off the west coast of Ireland on the 16th June, but no male could be obtained. He pointed out that the pale oil-globule sometimes presented a faint dull yellowish coloration round the edge, and that the capsule was thrown into ridges like those of the lemon-dab. He considers that the spawning-period is from April to the end of July. He again procured ripe females in the same region[1] and fertilized the eggs with milt of the dab, but they did not survive. He gives the dimension at 1·43, and the oil-globule ·24 to ·27 mm. Canu has also successfully hatched the eggs of this species, which he found pelagic from March to July. Ehrenbaum[2] has recently given a careful summary of the knowledge on the subject with additional observations of his own.

On the 30th April, 1891, a considerable number of the eggs of the brill (Plate IV, fig. 1) were obtained off Montrose by Mr Thomas Scott, F.L.S., the able and indefatigable naturalist on the staff of the Fishery Board, and fertilized at 7 p.m. with the milt of a male turbot, as no male brill was procurable. Both parents were of average size. Scott observed that the germinal disc was faintly visible at 8 a.m. on the 1st May, and more distinctly the same evening. On the morning of the 2nd May segmentation had commenced, and he forwarded the eggs to the St Andrews Marine Laboratory, which they reached at 3.30 the same day[3].

In the evening the disc was in the biconvex stage. Next day, 3rd May, the germinal cavity appeared (Plate IV, fig. 2), and on the 4th May the embryonic shield had formed. The egg on the 6th May (that is on the sixth day after fertilization) resembled that of the lemon-dab, though in regard to size it was larger, the diameter being about ·0555 inch or 1·4097 mm., the contraction after preservation in spirit reducing the size to ·048 or ·0495 inch, and picric acid causing even greater diminution.

[1] *Op. cit.* July 1893, p. 70.

[2] *Op. cit.* p. 291, Taf. vi. f. 22–24, 1896.

[3] W. C. M., *9th Ann. Rept. S. F. B.*, p. 317, Pl. XIII.

The capsule presents externally under the microscope an irregular basket-pattern, similar to that of the lemon-dab, and a slight sheen. In many, moreover, a series of minute globules formed a zone round the larger oil-globule. The blastoderm had not quite enveloped the yolk and the majority of the eggs were unhealthy or dead. Even temporary examination in several instances sufficed to prove fatal, a rare occurrence with healthy eggs. The embryo was outlined, and the optic vesicles distinct. On the 7th, closure of the blastopore took place, and next day Kupffer's vesicle appeared (Plate IV, fig. 3). On the 12th a considerable portion of the tail was free (Plate III, fig. 25). On the 13th May (13th day after fertilization), one or two emerged from the capsule, and floated languidly at the surface. A few escaped at intervals until the 15th May. On the whole, however, not more than twelve or fifteen were hatched out of the whole series, and the vitality of these was low, since none survived more than two or three days. The development of the brownish and black pigment on the trunk of the embryo was characteristic, approaching very closely the arrangement in the turbot, though the tints were by no means the same, since what was yellow in this species was reddish by transmitted light in the turbot. Yellowish and black chromatophores were present in connection with the oil-globule, and the yolk had numerous yellowish pigment-specks. The black chromatophores on the head and body were stellate or ramose, and minute black grains occurred in the eye. The skin was finely vesicular. It will thus be seen that the hybrid brill is much more boldly flecked with black, and that there is a tendency to yellowish as well as brownish in its coloration.

Immediately after extrusion the young hybrid (Plate XIII, fig. 7) was about 2·6 mm., as measured by Prof. Prince. The yolk-sac was large and round, with the oil-globule placed at the posterior border, and somewhat above the ventral edge. Its position thus corresponds nearly with that in the turbot. The head, body and marginal fin present a normal appearance, and differ from the sketch of the brill given by Dr Raffaele[1]. The dorsum of the head has black and brown pigment-corpuscles,

[1] *Op. cit.* tav. 4, fig. 18.

and the body is deeply tinted with the same characteristic brownish colour to the vertical caudal bars, black chromatophores being dotted all over the same region. The marginal fin has a patch of yellowish and brownish with a few black chromatophores just behind a vertical line from the posterior border of the yolk-sac, and thus it agrees with a similar patch in the turbot. As in the latter a bar of yellowish and brownish with a few black chromatophores occurs dorsally and ventrally, but it seems to be better developed in the turbot. Behind the touches mentioned, the brownish pigment of the body soon fades, yellowish-brown taking its place, and finally the tip is pale. The yolk-sac shows a series of black chromatophores along the upper and anterior arch, and at the oil-globule, brownish corpuscles along the anterior border, and yellowish with a few brown over the posterior half. From the foregoing it will be evident that the male parent had a potent influence in the position of the oil-globule, for in the larval brill, described and figured by Ehrenbaum and Canu, the oil-globule is situated near the ventral border of the yolk, somewhat behind the middle (Plate XX, fig. 1). Moreover, the length is 3·77 mm. After absorption of the yolk, Ehrenbaum states that the early post-larval brill has orange-yellow pigment, and resembles in outline the turbot of the same stage.

The next stage at which the brill has been met with is as a symmetrical pelagic young fish of 6—7 mm. (Plate XIII, fig. 8), with an eye on each side and brownish-yellow bars of pigment midway between the vent and the tail, that is, precisely in the position in which we find pigment in the larval fish. Traces of another bar of the same colour behind the latter also exist. Moreover, a brownish-yellow patch occurs in the dorsal fin in front, and the same pigment is found on the head and sides. The head, body, and tail have numerous finely marked black chromatophores, and a few of these occur in the pigment-bars on the fins. This size was reached on the 9th July (1890). No armature exists on the young fish at this stage. The black pigment is more pronounced in a young turbot of the same size. As Dr Petersen[1] truly says in his interesting discussion

[1] *Report of the Danish Zoological Station.* 1893. p. 133.

on this subject, the young turbot of the same size is somewhat in advance. This author gives a figure of a slightly larger form, viz. between 7 and 8 mm., and points out that while the turbot has spines on the head at this size, the brill has not. He also attaches some importance on the elevated ridge or hump on the head in the brill, nothing of the kind appearing in the young turbot. Moreover, at this length the brill has scarcely anything but embryonic rays in all the fins (which are formed), and the notochord is curved only a little upward.

A further stage of this species is represented by a form (Plate XIII, fig. 9) described in 1892 as an unknown post-larval fish from Smith Bank, where it was procured by the *Garland* in the mid-water net on the 28th June, 1889, along with young gadoids, gurnards and pleuronectids. In the original description it was contrasted with the halibut, but further consideration inclines us to think that it may be a well-grown young brill. It is distinguished by the great thickness of the body, the depth of which is comparatively moderate, by the character of the head, and the presence of branchiæ projecting behind the gill-cover. It is a post-larval fish, with a thick and firm body, and developing branchiæ, yet the embryonic tail is still present. Its total length is 9·5 mm., and the greatest depth is about 3·8 mm. The body is somewhat elongated, with a distinct depression of the snout in profile, as in the young brill, and a marginal fold on the head joins the anterior part of the dorsal fin. Indications of very minute spines occur on the opercular region.

The body is speckled with minute blackish-brown points on the head and lateral region, and by similar specks of pigment over the belly, the latter having undergone considerable change, as is often seen in other forms after immersion in spirit, viz. a spreading out of the marginal pigment, while a black speck remains in the centre. The specks on the lateral region are dotted with some regularity. Indications of two pigment-touches occur in the dorsal (marginal) fin, viz. above the tip of the breast-fin, and another about the centre of the region behind the vent. Ventrally a single patch lies between the vent and the tail. A little pigment occurs on the under surface of the belly, and behind the vent is an indication of an anterior pigment-bar. The coloration is alike on both sides of the fish, as usual in such pelagic forms.

The eyes are of considerable size, and are lateral in position, that is, one occurs on each side of the body. The animal is as yet too young for any change to be visible in the left eye. The vent is situated a little in advance of the median line of the body.

The marginal fin is somewhat injured, but it seems to have been of moderate depth, and traces of true rays appear both dorsally and ventrally, though the free edge is wholly embryonic. The tail shows dorsally the terminal bend of the notochord (early backbone), but it does not taper much, and the embryonic fin forms an apparently shorter lobe than in the flat fishes hitherto examined. Moreover, on comparison with young turbot at the same stage of development, the difference in size is marked. Before the turbot reaches the length of the present form (brill) it has lost the characters still found in the latter, *e.g.* the embryonic lobe at the upper region of the tail, which has its permanent inferior part furnished with much more developed true rays than in the young fish from Smith Bank.

The brill has an egg considerably larger than that of the turbot, so that the larval fish starts life in advance of the turbot in size. Consequently the post-larval turbot at a given size is an older fish than the brill, and its organs are further advanced.

In what appears to be a brill of 11 mm. (Plate XIII, fig. 10), procured at the surface on the 23rd June, 12—14 miles from the coast of Aberdeen, further progress has been made. In life it much resembled a young flounder in colour and was difficult to detect; indeed the attendant lost it in the jar, and only recovered it after death had made the tissues more opaque. When it reached the Marine Laboratory it was more or less in the latter condition, with a slightly yellowish hue of the body, which, with the head, was dotted all over with large and small black chromatophores. The dorsal fin, which had true rays, had six black touches, and portions of two were present in the anal, which with the abdomen had been injured. The most distinct of these began at the inner margin of the interspinous bones, and proceeded outwards into the fin-rays almost to the tip. The black pigment on the head was irregularly scattered, and the same may be said of that on the body, though, in the case of the latter, the larger chromatophores were observed to be densest in two longitudinal streaks separated by a pale band which passed forward to the gill-cover rather above the eye. The eyes are large and silvery, while the great size of the head, the structure of the mouth and the hyoidean region, are characteristic. The head is so large that it is only about a fifth less than half the diameter of the entire animal to the posterior border of the hypurals. Minute spines occur along the opercular border and a portion of the surface inferiorly, as well as above the eyes and elsewhere over the snout. Such spines are characteristic of the somewhat later stages of the turbot at the length of 14 mm., in which the opisthure (terminal region of the notochord) is still very evident at the upper border of the caudal, and also a slightly older specimen figured in the "Marine Invertebrates and Fishes of St Andrews" (Plate VI, figs. 5 and 6). Dr Petersen has observed them in the young brill. At this stage the young fish is provided with an air-bladder for its pelagic life. The larval tail is still present superiorly as a distinct fin with its embryonic rays, while the true rays of the caudal occur beneath.

In the Danish waters in July Petersen has found young brill of from 6 to 8 mm. without spines, and with a straight notochord (Plate XIII, fig. 11). The next older stage which he shows has the notochord bent up and spines on the operculum, while the median fins have true rays, but the pectoral has only embryonic rays (Plate XIII, fig. 12). Those off the east coast of Scotland are generally larger, and in continuation of those just described. Thus on the 11th July an example 15 mm. long was captured in the bottom-net in St Andrews Bay. The eye is somewhat further over than in a turbot of the same length, but similar though smaller spines occur on the pre- and sub-operculum, and along the mandible. The head is, however, proportionally large. The dorsal fin has seven touches of dark pigment, and the anal four distinct touches, and a small patch opposite the seventh dorsal. The fins do not show the general dusting of pigment seen in the turbot, and thus its condition corresponds with Raffaele's drawings of the brill[1].

Another of 24 mm. comes, on the 25th of the same month (July), from the tidal margin of the estuary of the Eden. In coloration it corresponds with the brill, but the right side has a general distribution of blackish chromatophores. The right eye is not so far to the left as might have been anticipated, for the dorsal fin has not reached the central line of the eye. The dorsal has 74 rays, and the anal 56 to 57 rays. The spines have disappeared.

In August, those captured ranged from 22 to 29 mm. The former, which also occurred in the hand-net at the tidal margin of the Eden, has a general resemblance to a brill. A hard patch occurs on each otocyst. The pigment is as in the foregoing specimen. Both eyes are on the left, and the dorsal fin has advanced to the mid-ocular region. The dorsal has 75 rays; the anal has 54. The example at 29 mm. was procured in the trawl on the 20th August, and also is brill-like. The right side still has many blackish pigment-specks, as in the younger forms. Each otocyst has a hard patch. The dorsal fin has advanced considerably in front of the right eye, which is separated by a distinct space from the fin. The dorsal has 75 or 76 rays, the anal 59. Scales are not yet developed. Petersen found the number of fin-rays in brill from 11 to 182 mm. to be, for the dorsal 70—80, most having 73 to 75; for the anal, 51 to 60, most having 53—56[2].

In September specimens of 50 and 61 mm. occurred in the seine or sand-eel net on the East sands, St Andrews. They are apparently miniature adults, though in the smaller the curve of the lateral line anteriorly was faintly marked. These would probably be in their fourth or fifth month.

At Plymouth examples in October ranged from 2·8 to 3·9 inches, and as they were reared by Mr Cunningham in the aquarium, there can be no dubiety about their age (6 months).

[1] *Mittheilungen a. d. Zoolog. St. Neapel*, VIII., Taf. 4 f. 8. 11, 15.

[2] *Op. cit.* p. 134.

When, however, we come to Cunningham's examples of the following April, viz. 3·3 to 3·7 inches in the aquarium, it is clear that the growth of these captive specimens falls short of that in nature, unless the brill of the south differs materially in this respect from the northern. On the east coast they attain the length of about 5 inches in May; and in September are often met with of 10 to 11 inches, which probably represents the growth of a year and four or five months. Cunningham's example of 7·2 inches was probably a small one, or pertained to a less vigorous race. The time which would elapse before the brill of the east coast would reach 18 inches is therefore not necessarily four years.

Müller's Topknot. (*Zeugopterus punctatus*, Bl.)

As described in the *Researches*[1], a specimen with distended ovaries having a few ripe eggs was found in a pool on the 16th May. In the *Scandinavian Fishes* the spawning-season is stated to be in spring and summer. Malm, again, found a ripe female on the 11th June. The translucent (nearly ripe) ova had a diameter of ·042 in., that of the conspicuous oil-globule being ·008 (Plate IV, fig. 6). During the same month and till July certain ova are common in the bottom tow-nets in St Andrews Bay, measuring ·034 by ·035 in., or ·996 mm. (Plate IV, fig. 7). In the majority of those captured in the bay the embryos were far advanced, as if they had been carried by currents some distance. Yellowish pigment early appears in the embryo, viz. shortly after the lenses are distinct. Before hatching, the yolk and general surface are observed to be reticulated and slightly papillose, or, as Mr Holt aptly terms it, the whole surface exhibits a remarkable epidermal network consisting of small vesicular bodies connected with each other by fine lines. Active movements occurred in the advanced embryo, though the impression was that the heart was somewhat later in commencing to pulsate than in the cod.

After extrusion the larval fish (Plate XIV, fig. 1) measures about $\frac{1}{10}$th of an inch, and is characterised by the presence of

[1] McIntosh and Prince, *Trans. R. S. E.*, p. 852.

yellowish pigment along the marginal fin dorsally and ventrally, blackish grains occurring amongst the rest. The tip of the tail, however, remains translucent. The general surface of the head, body and yolk-sac is dotted with yellowish pigment, and a few black chromatophores are present on the yolk and oil-globule. No colour appears in the eyes. The oil-globule is placed inferiorly—distinctly behind the middle of the yolk-sac, but a considerable interval exists between it and the posterior border of the latter. Moreover, the entire surface of the larva is covered with the somewhat coarse reticulations formerly alluded to. The posterior end of the gut in some does not extend to the margin of the fin. On the third day after hatching the mouth has not yet opened, and the only new feature is the more general distribution of the pigment. At first the latter does not enter the marginal fin, but by and by it does so. Two slight folds of skin from the oil-globule forward on each side of the yolk are occasionally seen. The notochord is multicolumnar.

The larval fish was kept till the yolk and oil-globule had disappeared. The chief change was the more conspicuous nature of the yellowish (gamboge) hue along the margin of the dorsal fin, which has greatly increased in depth. The head also assumed a deeper yellow hue from the pigment over the brain, and the body was covered with many minute yellow chromatophores mingled with black. The breast-fins were small and tipped with yellow, and had streaked basal regions. The eyes were greenish silvery. The mouth was now widely open. The space between the rectum and the yolk was marked.

In the *Researches*, a post-larval form not uncommon in deep water, especially south-east of the Isle of May in August, was described, but its relationships were somewhat uncertain, though it was then considered to belong to a sinistral flat fish (pleuronectid). Holt[1] and one of us[2] have since re-examined it, and we are inclined to relegate it to the topknots. The earliest stage is about 6—7 mm. in length (Plate XIV, fig. 4). The head is large, and the gape is even more so, the eyes small, and

[1] *Trans. R. Dubl. Soc.* v. ii., 1893. p. 104.

[2] W. C. M. 10*th Ann. Rept. S. F. B.*, 1892. p. 274 &c.

the general colour of the body yellowish or buff, though the middle of the tail-region is profusely speckled with black, and similar pigment occurs on the head, jaws and other parts. The fish at this stage is as symmetrical as a round fish, only a very slight elevation of the right eye having taken place, and it is a free-swimming form for a considerable period.

In the next stage the body increases in depth, though little if any in length, and the space between the vent and the snout is longer. The true tail is developing below the larval tail which projects prominently above it, and which has temporary (embryonic) rays (Plate XIV, fig. 3). Thereafter the body becomes somewhat triangular in outline, so that while the length is only 6 mm. the greatest vertical diameter is 3 mm. The head of the fish is still disproportionately large—larger than is usual in such forms. The dorsal line is nearly straight from a point above the otocysts (ears) to the base of the tail, but the ventral line slopes rapidly downward from the tail to the vent, and again rises, with an anterior convexity, to the jaw. Holt finds a little over 70 rays in the dorsal, and about 65 in the anal fin, in a similar example from Ireland. Papillæ indicate the developing ventral fins. Both surfaces of the body are minutely speckled with black points, but the right is more uniformly marked in this way. The specks extend to the marginal fins, but not over them.

The changes which follow, as seen in the next older forms (Plate XIV, fig. 6), are the slight increase in the depth and plumpness of the body posteriorly, the elongation of the rays of the marginal fin, and the appearance of five or six touches, caused by aggregations of dots, in the dorsal, the ventral still remaining speckled as before. The closely approximated ventral fins have likewise minute black points, but the breast-fins remain pale. The right eye meanwhile is gradually passing upward, and the embryonic fin is rapidly disappearing.

The next phase (Plate XIV, fig. 7) consists in the extension of the abdominal wall ventrally, the increase in the distribution of the pigment,—the left side still remaining slightly speckled, while the right is densely coloured,—the more evident grouping of the pigment in "touches" in the fins both dorsally and ventrally, and in the progress of the right eye towards the left. The marked notch behind the angle of the mandible, and the elevation of the head behind the right eye, are also noteworthy features. When the right eye mounts the dorsum, the dorsal fin forms a high arch behind it. The body, moreover, has considerably increased in depth in comparison with its length, a specimen about 9 mm. in total length having a depth of 6 mm. Besides the "touches" of pigment on the fins, a few minute black points are scattered over the left surface—the right being covered with minute dots almost as densely as before. In Holt's examples from the Irish Sea, a reduction of pigment took place from about 7·25 mm., just before the arrangement in "touches" occurred. Holt in his oldest stages counted from 70 to 80 rays in the dorsal, and from 60 to 65 rays in the anal fin. He carefully discusses the question to which species of topknot his examples most probably belong, and concludes that it is Bloch's topknot (*Rhombus unimaculatus*). In regard to the form described in the preceding pages, however, the post-larval stages probably belong to Müller's topknot, the most common species; indeed Bloch's topknot is unknown in the neighbourhood, though the Norwegian topknot is occasionally found.

Dr Petersen mentions a specimen of 13 mm. captured by Prof. Sars in August, in which the characters were nearly those of the adult, except that the pectorals had only traces of true rays. "The distribution of the colours is peculiar, the left side being dotted with round dark spots of about the same size, evenly distributed over the whole fish, head, body and fins, and amongst these spots are pointed, soft warts like those which are found in somewhat older animals[1]."

Of the subsequent stages of Müller's topknot, a specimen of 41·5 mm. was tossed on shore after a storm on January 16, 1895 (Plate XIV, fig. 9). The greatest diameter (across fins) was 24·5 mm. The left side is dappled with distinct black spots—one of which runs obliquely from each eye. They are independent of the dark touches which mark the dorsal and anal fins. A series of small pale specks are also dotted over the

[1] *Op. cit.* p. 135.

posterior half of the same side, some of which at least are not due to injury. The scales are small and of a less perfect shape than in the subsequent stages, the number of concentric rings for instance being fewer. The lateral spines are proportionally long. Comparatively few, viz., three, four or five, of the crenations, with the lines interrupting the concentric circles, occur posteriorly, whereas in the adult about a dozen are present. In many of the smaller scales only three spines exist, and the median is smaller than the lateral.

The next older stage is one 70 mm. in length, procured on the same date (16th January), which represents a considerably more advanced condition. The left eye appears more distinctly in advance of the right. The scales now form a single plate with concentric lines, the large central spine has greatly increased in size in proportion to the lateral, and the number of concentric rings is larger.

These scales differ from those of the adult in being much smaller, with fewer concentric lines, which moreover are wider apart. The crenated anterior border is also feebly developed, whereas in the adult it is a marked feature. Besides the spines visible on the edge of the scale, the exposed surface has several near the base of the large median one, and within the adjacent border.

The authors of the *Scandinavian Fishes* state that "In September the young have attained a length of about 25 mm."

THE NORWEGIAN OR EKSTRÖM'S TOPKNOT. (*Rhombus norvegicus*, Gthr. = *Scophthalmus norvegicus*, Smitt.)

Mr Cunningham found on July 9th specimens, at first thought to be Müller's topknot, ranging from 2·4 to 3·7 inches. Moreover in March he found one a little over 3 inches quite ripe, the pelagic ova measuring ·9 mm. in diameter, and containing a single oil-globule ·15 mm. in diameter.

In a female examined at St Andrews on the 6th April[1], the ovarian eggs were small, ranging from 0·34 to 0·152 mm., so

[1] *Vide* W. C. M. *12th Ann. Rep. F. S. B.* p. 227, Pl. IV, fig. 5.

that the spawning-period was probably not nearer than July, a supposition which Cunningham's remarks corroborate.

Remarks on Young Topknots.

In connection with the foregoing are certain curious forms, the early stages of which were found by Mr Holt in May, 1891, during the Survey of the Fishing-Grounds on the west coast of Ireland under Mr Green and Prof. Haddon. They are recognized by their dense black pigmentation (Plate XIV, fig. 2). At 5·87 mm. the eyes are symmetrical, snout long, angle of the jaw prominent, the body elongated and the notochord straight. The marginal fins are broad, but without rays, except embryonic in the tail-region. A pre-anal region is present, and the vent opens at the edge. The breast-fins are lobate, and the pelvic fins are rudimentary. One of the most conspicuous features, however, is the presence of a pair of large compressed spines on the external wall of the ear-cyst. The pigment is mainly black, but greenish-yellow is also present over the brain and along the dorsal and ventral lines. A median line of pigment occurs on the belly, and a line of black with a few yellow specks on either side of it. The latter form a loop. Six very distinct pigment-patches occur on the dorsal, and four—not including the hypural—on the post-anal fin. The pigment of the trunk is not broken up into bars. The base of the breast-fin is also pigmented, and grains of the same occur on the sides of the head and jaws, and on the snout[1]. The largest example measured 10·62 mm., and the condition of the eye on the right shows that it is a sinistral form with fin rays,—D. about 80 and anal about 66. Little change had taken place in the pigment, or in the spines over the ear.

Holt's view that these young forms pertained either to the brill or to the Norway topknot was a reasonable one. The young brill, however, at the stage reached by these specimens, is a larger and thicker fish, the pigment and general outline differ, and it has no spines on the ear-capsules. Holt points out, again, that the fin-ray formula of the Norwegian

[1] Mr Holt, *Trans. R. Dubl. Soc.* Vol. v, p. 112, 1893.

topknot agrees with that found in his oldest specimen, viz. Dorsal 80, Anal 66. He also found a series of small spines in an adult behind and along the gill-covers. These, however, may be only longer median spines of the scales of the region.

Between the stage just described, and measuring 10·62 mm., and what appears to be an older condition of the same form, no intermediate examples are known, yet the gap is by no means wide. In Holt's oldest form the eyes are still lateral, though the right eye has begun to move. In those procured on the east coast of Scotland, the length is less than that of Holt's oldest form, but the body is broader, and the shape and arrangement of the fins are more like those of the adult. In what appears to be the youngest specimen procured at the surface on Smith Bank, off Caithness, the length is 10 mm. (in spirit), and the right eye is almost invisible from the left, only a faint crest indicating it. None of the pigment is visible. The fish appears to be considerably older than Holt's, since the larval tail has disappeared, and the body has greatly increased in breadth. The shape of the head, the prominent angle of jaw, the comparative size of the eye, the ear-spines and the gap behind the ventral fins are characteristic (Plate XIV, fig. 5).

In the next stage, procured on the 10th September in St Andrews Bay in the mid-water net, the length is about 11 mm. in spirit, and the right eye viewed from the left is distinctly seen above the ridge. In other respects it agrees with the former.

In the stage (Plate XIV, fig. 8) procured on the 31st August, at 22 fathoms south-east of the Isle of May, the length is but 11 mm.[1] and the eye is on the ridge, being best seen from above. The ear-spines and other distinctive characters are present. The right surface is pale—with the exception of a few irregular black specks and touches, while the left is streaked with black pigment-bands, which have a remarkably regular arrangement, the touches in both dorsal and anal fins being joined by intermediate streaks, the head and abdomen only showing scattered points. The pelvic fins

[1] The size formerly given was 9·8 mm. in length and 7 mm. in breadth, but with a more accurate scale the length is as stated above.

still show pigment-streaks, and thus are in uniformity with the anal in a lateral view. The dorsal and anal fins have long rays towards their posterior borders, and the body of the fish is somewhat quadrate in form. The dorsal fin presents 87 rays, and the anal 62. On contrasting these with the forms described under Müller's topknot, and the largest of which measures about 9·5 mm. (see fig.), it is clear that the present forms are much older. Yet the right eye is either just visible from the left, or at any rate is much less advanced towards the left than in the oldest stage of what we have considered to be Müller's topknot. This would indicate, as formerly stated by one of us, that the latter (*i.e.* the present form), in all probability, belongs to a smaller species, a conclusion which Holt's further observations seem to corroborate, that species probably being the Norwegian topknot, which occurs occasionally off St Andrews Bay and along the eastern coast of Scotland to the Moray Frith. It is also found on the west coast, and stretches to the shores of Norway.

Mr Cunningham thinks[1], from the number of the fin-rays and the appearance of an example he examined, that the foregoing are the "larvæ" of Müller's topknot, while the forms here mentioned under Müller's topknot (p. 346), and which have no spines, belong to the one-spotted topknot. With this opinion we are unable to concur, and besides, while Müller's topknot is not uncommon in this region, no example of the one-spotted form has ever been obtained.

THE SAIL-FLUKE. (*Lepidorhombus whiff.* (Penn.) Walb.)

The earlier authors do not appear to have seen a ripe sail-fluke, or "megrim," as it is often called by the Scottish fishermen. No mention of the subject is made by Parnell or Couch, while Day only quotes Thompson of Belfast as to an example which had just shed its eggs on the 31st October. The authors of the *Scandinavian Fishes* mention that Düben and Koren assume the spawning-season to be spring, as they took a female with well-developed ovaries on the 4th April. Raffaele

[1] *Marketable Fishes*, p. 278.

pointed out that the eggs of this genus have a single oil-globule, and his figure resembles the eggs of the present species, though he does not show the minute structure of the capsule. His figure of the larval fish probably refers to the Scald-fish (*A. laterna*) or other form, and the same may be said of the post-larval example with a long ray like a whip anteriorly.

Mr Holt, who found ripe forms of both sexes off the west coast of Ireland in March, April and May 1891, considered that spawning takes place in moderately or in very deep water, and necessarily in our country therefore at some distance from shore where the declivity is gradual. It has long been known as an inhabitant of the deep water off the east coast of Scotland. The eggs (Plate IV, fig. 4) are transparent, have a diameter of 1·430 mm., and the oil-globule ·3048 mm. Like the eggs of the brill and lemon-dab, the capsule is covered with raised lines or ridges with very fine striæ between them, the usual minute punctures being densely dotted over the surface. The raised lines and ridges are present in the capsule after hatching has taken place. The micropyle is difficult to distinguish, but it appears to be sometimes situated in the centre of a radiate series of lines in a space bounded by other ridges. It is best seen by placing several eggs together on the bottom, so that they support each other, and give special positions not seen when each is free.

Development progressed with considerable rapidity, so that on the second day (29th May) the rim had either reached the equator (centre of the egg) or extended beyond it, and it clasped the yolk so tightly that a dimple was often present on each side. On the third day, black pigment-corpuscles appeared on the tail of the embryo and under the oil-globule, while the lenses were also present. On the fourth day, the ramification of the pigment-corpuscles was conspicuous, and they extended along the sides. The heart exhibited faint contractions. They hatched on the 5th day.

The larva (Plate XIV, fig. 10) possesses only black pigment, which is somewhat uniformly scattered over the body, a few specks only occurring on the head. These pigment-grains also extend on the marginal fin both dorsally and ventrally. Thus five or six V-shaped chromatophores are found near the margin of the dorsal fin behind the yolk-sac, almost intermediate between it and the tip of the tail, and two similar, or sometimes triangular ones are present ventrally opposite the former. The large oil-globule (slightly elliptical in certain views) lies at the posterior and inferior part of the yolk, and has the usual black chromatophores. The ears form simple sacs, and the eyes are colourless. The rudimentary backbone (notochord) is distinctly multicolumnar. The solid strand of the gut posteriorly comes to the edge of the marginal fin, and a pre-anal portion occurs between it and the yolk.

On the third day of larval life, yellow pigment is apparent amongst the black in the marginal fin, and along the sides of the body posteriorly. None is present on the head. The yolk-sac as a rule has no pigment, though occasionally one or two black corpuscles appear at the upper region. It has to be noted, however, in the case of those retained longer in the egg, that yellow pigment occurs on the tail. The mouth is widely open on the 6th day, and the yellow pigment is largely increased along the muscle-plates, pre-anal region and other parts. Black pigment is developed in the eyes on the seventh day, and the yolk has greatly diminished. Though the cartilages of the jaws are much less developed than in the gadoids, yet the aperture of the mouth is proportionally large and the movements extensive (Plate XIV, fig. 11).

The larva of this species is thus distinctly characterised, and can be readily separated from that of the gurnard or other forms with which it has occasionally been confounded. The eggs are comparatively large and not very numerous, while the adult is seldom procured in numbers.

Holt found a series of small specimens off the Skelligs on the west coast of Ireland, on the 19th August, ranging from 19 (Plate XIV, fig. 12) to 56 mm.[1] The right eye has passed the ridge at 19 mm., is a little in advance of the left, but is upwardly directed; the lateral line is visible, but its anterior portion has only a simple curve. Indications of the pigment-

[1] Specimens from 30 to 40 mm. in length also occurred in July in the same area.

patches are observed along the base of the dorsal and ventral fins. At 30 mm. both eyes are on the same level and the long axis of the right eye is parallel to that of the body. The patches of pigment are more clearly defined. The lateral line retains its simple curve. Scales are now present.

At 50 mm. the contour is more like that of the adult, scales occur everywhere except on the head, the anterior part of abdomen and the interspinous areas, and the curve of the lateral line anteriorly has assumed much of the angular condition of the adult. The pigment-patches in the interspinous region are reduced. At 90·4 mm. the head and parts of the interspinous regions are devoid of scales, and the black pigment is still further diminished. He procured other young samples up to 180 mm., and none were obtained from a less depth than 28 to 32 fathoms, whilst one occurred at 115 fathoms. He concludes by estimating that those from 19 to 56 mm. are from 3 to 7 months old; those from 75 to 130 mm. from 15 to 19 months; while those from 150 to 250 mm. are from 27 to 31 months.

THE SCALD-FISH. (*Platophrys laterna*, Walb.)

The authors of the *Scandinavian Fishes* are of opinion that the spawning-season of this form occurs between May and August, and Collett estimates the number of eggs at 50,000. Malm, again, found ripe specimens between the 9th and 21st of August, and remarked that it was at the latter date that the roe began to "run."

Cunningham believes the spawning-period is in May or June. Holt found a ripe male off the west coast of Ireland in April. Raffaele[1] first described the egg, but did not give the species.

Ehrenbaum[2] recently found in July at some depth an egg measuring 0·659 mm. with an oil-globule, and resembling a rockling's, which he identified with this species. The larval fish on hatching measured 2·575 mm. and had an elongated yolk-sac, with the oil-globule at the posterior border —just in front of the rectum (Plate XIX, fig. 9). Touches

[1] *Op. cit.* p. 49, Tav. 4, f. 20.
[2] *Op. cit.* p. 299, Taf. v, fig. 25–29.

of red or brownish pigment occurred along the dorsum, two in the dorsal marginal fin and one on the trunk behind the vent. He followed the larva into the post-larval stage, with the long dorsal process from the head (Plate XX, fig. 3), then into the metamorphosed condition of 16—18 mm. in August. Petersen found one of 23 mm. with scales.

Cunningham obtained small specimens in shallow water (3—5 fathoms) near Plymouth in October, their length being from an inch to 1·4 in. and he thought them 4—5 months old (Plate XIV, fig. 13, after Holt). In February they were from 1·8 to 2·5 inches, and then probably from 8—9 months old. They reached 1·9 in. in May at the age of 11 months. The following February they occurred in deeper water 3·7 to 4·7 inches, and he estimated the age 1 year and 3 months. In September many of 3 to 5 inches were procured also in deeper water, and he considered these a year and three months old. They were sexually mature at 5·8 inches, and these he states were over two years. The adult males are easily recognized by the sudden elongation of the anterior dorsal fin-rays. Like other flat-fishes the young seek the shallow sandy margins, migrating outwards as they grow older, and being especially abundant in the south between 20 and 30 fathoms.

Holt, again, mentions several of 25 mm. trawled at 41 fathoms in August, off Ballycottin, Ireland. Black pigment is distributed in small dots, in patches on the jaws and head, and a line of chromatophores runs along the base of the inter-spinous ridges. Streaks of black occur at intervals along the rays of the dorsal and anal fins, and two patches on the caudal fin.

From the west coast of Ireland occur specimens from $2\frac{3}{4}$ to $3\frac{1}{4}$ inches in length in the month of July. By Cunningham's estimate these should be about a year old.

The Plaice. (*Pleuronectes platessa*, L.)

This fish is perhaps the best known of the flat-fish group, and it has also the earliest spawning-period. Quite at the commencement of the year, towards the end of the first month, the eggs of the plaice occurring in the surface-nets indicate that the spawning-season of the food-fishes has begun. On through February and March their numbers increase, and then become less and less, until by the end of May they are of rare occurrence, mostly at Smith Bank. As in other species, the reproductive period of the plaice appears to vary considerably in different localities—thus Petersen and other observers in the Danish waters find that this fish may even commence spawning in November and December. In Sweden the spawning-season is April, while at Heligoland, Ehrenbaum gives from January to March.

It seldom appears to spawn within the territorial waters, unless where the bottom shelves rapidly into deep water, but its eggs are found in great abundance with those of the haddock some distance east of the Island of May and near the Bell Rock.

The egg is pelagic and is of large size (see Table), the mean diameter being about ·069 inch or about 1·79[1] mm. The egg-capsule exhibits a great number of minute punctures, and its surface, in addition, is corrugated, having a sheen in good light. There is no oil-globule.

The plaice appears to be by no means so prolific as some of its near allies, one female producing, on the average, about a quarter-million eggs, though as many as 480,000 have been recorded. The period of incubation is long, corresponding with the early spawning-habit. Eggs fertilised in January at Dunbar hatched in about 16 to 18 days, whilst those hatched here in April had the period of incubation reduced to 8 or 9 days.

These results are confirmed and extended by the recent experiments of Dannevig at Dunbar. He found that within certain limits the duration of the hatching-period could be extended or curtailed at will by suitable variations in the temperature of the surrounding medium. These results apply with equal force in the case of several other species as well as the plaice, and have an important bearing upon the questions of distribution, the fate of the larvæ and other points.

In the eggs developed in April, the usual series of phenomena give rise to the embryo, which on the seventh day is very

[1] Ross's micrometer, St Andrews' scale.

conspicuous, being coiled in the egg-capsule (Plate IV, fig. 14). It is dotted all over the head and body with a great number of little round spots of a bright yellow colour, and less numerous branched black chromatophores which take up a rather more definite arrangement, being somewhat evenly scattered over the trunk but collected together in masses upon the dorsal surface of the head. The eyes at first show a reddish-golden lustre but as development proceeds they acquire the characteristic silvery sheen of the larval and post-larval stages.

Two days after this the capsule bursts and the larva measuring about 6 mm. (Ehrenbaum gives 7·5 mm.) emerges. The pigmentation does not differ in very essential respects from that of the embryo, but it has assumed a more definite arrangement. The black chromatophores are mainly confined to a dorsal and a ventral row, running longitudinally along the body, with a few scattered stellate spots upon the surface of the yolk-sac; the yellow pigmentation, on the contrary, is still in the diffuse condition, small yellow spots being dusted over the body and marginal fin. Apart from these features, the large size of the larva together with the broad marginal fin are diagnostic.

Having followed the life-history of the plaice up to this point we may mention the peculiar *rôle* which has been assigned to the shrimp in connection with this fish. Day states that the opinion was at one time held that the shrimp was actually a stage in the life-history of the plaice, a piscine larval form in fact, which by a direct metamorphosis gave rise later to the latter. Naturalists did not at first succeed in demonstrating the want of truth in this fable. Deslandes, amongst others, reported that shrimps kept under observation in a vessel of sea-water gave rise, in his opinion, to young plaice, though he did not elucidate the stages in the process. He supposed that the eggs carried about by the parent-crustacean below its body were eggs of the plaice, which reached the hatching-stage only when thus taken care of by the strange foster-parent. Lacépède, following up this line of thought, attempted to account for the presence of eggs on the undersurface of shrimps by the suggestion that they adhered to the latter whilst they were attempting to devour the masses of the ova of the plaice, which were supposed at that time to abound inshore upon the sea-floor.

The light of further research shows us that the shrimp carries its own eggs below its body, and also that the plaice sheds its eggs out at sea far away from the sandy shallows haunted by the shrimp. The only real connection that exists between the history of the shrimp and that of the plaice is that the one constitutes a staple article of diet for the other.

By the time that the larval plaice has reached the age of one week some changes have taken place in the arrangement of the pigment. It has increased to a length of $\frac{1}{3}$ inch and the supply of yolk has diminished with a corresponding reduction in size of the yolk-sac.

The black pigment consists of a few minute spots on the head and a number of branching ones upon the trunk (Plate XV, fig. 1). The smaller chromatophores are situated upon the ventral marginal fin, and the larger are crowded together in the lateral region above the vent, on the under-surface of the stomach and in a dorsal and ventral row down the trunk, extending nearly to the tail. The yellow pigment, so conspicuous in the embryo, and the presence of which is a characteristic feature of the pleuronectids, is now confined to a small area, as a row of bright spots along the hind-dorsal border of the trunk. This coloration, in its general characters, persists to the close of larval life. The little animal is very transparent and is not easily recognised except by its pair of glittering eyes. Confined in small tanks, it frequently bores its snout into the sand and lies on one side upon it, a habit probably due to the abnormal circumstances under which it is placed in the laboratory.

One or two of the earliest post-larval forms have been well figured by Dr Ehrenbaum[1] and they fill in the gap between the preceding and the youngest free forms caught in the tow-nets, which are nearly half-an-inch in length (Plate XV, figs. 2 and 3). They occur mostly in April in St Andrews Bay. The smallest are still perfectly symmetrical, but in the larger ones the left eye has begun its extraordinary journey, and

[1] *Eier u. Larven von Fischen der deutschen Bucht. Wissensch. Meers*, 1896.

has even reached the dorsal ridge marking the separation between the two sides. The pigment is still symmetrically arranged on both sides, the black spots being principally located upon the ventral margin of the trunk but in some they extend up the sides and the hind-dorsal region.

These little post-larval pleuronectids are distinguished as such from the gadoid and other families by the great depth of the body and of the marginal fin. They are found in great numbers in the surface and mid-water and appear to move further down towards the sea-bottom as age advances. Along with the downward migration appears a tendency, coincident with the change in the eyes, to move more and more upon one side until, by the time the little fish takes up its habitat upon the sandy bottom, it rests, as already indicated, upon its left side. The pigmentation on this side gradually disappears, leaving a pearly white surface, so familiar in the adult. This disappearance of pigment seems to be the direct effect of the reaction of the organism to the absence of light.

At a length of 10 mm. (or about $\frac{2}{5}$ inch) the little pelagic plaice (Plate XV, fig. 2) show signs of commencing metamorphosis[1]. The left eye appears on the dorsal ridge of the head in its migration over to the right side. Holt[2] gives the following diagnostic characters for the young plaice at this size. "The head is contained four times, and the greatest height of the body (without fins) three times, in the total length, without the caudal fin....Very little black pigment is present on the body. The dorsal interspinous patches are merely marked by a few chromatophores. Rather more pigment occurs ventrally, but it is somewhat diffuse, except along the pre-anal ventral outline. A little is present internal to the otocysts, on the sheath of the notochord, and along the renal region." There seemed to be no coloured pigment. The dorsal fin showed 62 fin rays and the anal 48. We may add that the black pigment tends to collect in three or four patches dorsally and ventrally.

[1] Möbius and Heincke found that the transference of the eye in an aquarium took about 4 weeks.

[2] *Transactions of the Royal Dublin Society*, 1893, p. 77.

Further development consists in a reduction of *comparative* length, so that in the stage 12 mm. long the length of the body is only $3\frac{1}{3}$ that of the head, and only $2\frac{1}{2}$ times the greatest breadth (height). The dorsal and ventral patches of pigment are still more pronounced, and the pigment of the tail forms a single transverse bar. The number of dorsal fin-rays has increased to 72 and the anal rays to 54.

At a length of 12·87 mm., or a little under $\frac{1}{2}$ inch (Plate XV, fig. 3), there are several marked differences from the preceding. The body has still further increased in proportionate breadth, the length being about $2\frac{1}{4}$ times the length. The eye is well on the right side and the dorsal fin has advanced forward to just below its hind border. The black pigment is more plentiful and has invaded the dorsal and anal fins. The lateral line can now be traced, and little groups of brownish pigment-spots are grouped over the ocular side, on the future upper surface. These give the little fish a brownish-grey colour. The specimen figured had 68 dorsal fin-rays and 55 anal.

In Plate XV, fig. 4, is seen the young plaice of 21 mm. length (or about $\frac{4}{5}$ inch). Although in some respects differing from the adult, yet it could not at this stage be mistaken for any other species. The breadth (height) is now about half the length and both eyes rest on the right side. The forward migration of the dorsal fin is almost complete. The groups of brown spots have now been broken up and the whole right side is covered with diffusely distributed brown pigment.

The young fish is completely equipped for a life on the bottom, with brown coloration in harmony with its sandy surroundings (Plate XV, fig. 5). As already stated, the pelagic habitat is forsaken at a stage of about $\frac{1}{2}$ inch in length, so that the brown pigment and most of the black appear after the change to a 'bottom' life.

As regards the distinction between the young plaice at these 'bottom' stages, and the young dabs and flounders at the same stage, we must refer the reader to the parts under the headings 'Dab' and 'Flounder.' We may here mention that the number of fin rays in the young plaice from 11 to 53 mm. in length varied from 80 to 61 in the dorsal fin and 57 to 46 in the anal fin[1]. The grey colour, the dark brown and red spots, deeper form of the body and the shorter peduncle of the tail, the length of the base of the anal fin (more than half that of the body) are points given by the authors of the *Scandinavian Fishes* as distinctive.

The young plaice from an inch upwards are very abundant in shallow sandy bays and immense quantities of them are caught in shrimp-nets. As they grow older and larger they move further and further out to sea, so that few over 11 inches in length are found within the three-mile limit. This regular distribution and correspondence between size and distance from the shore[2] is also found in some other pleuronectids and, although it is probably a habit beneficial to the species under natural conditions, yet it exposes their youngest stages to destruction in enormous numbers by shrimpers and others.

The plaice arrives at a state of maturity when at an average length of about 12 inches (more off the Scotch coast) and is then found in the deeper waters. Fulton gives the results of a series of experiments conducted by means of marking a great number of plaice and setting them free, which tend to confirm the opinions which had already been expressed by one of us with regard to the migrations and life-habitat of the plaice. He summarises his conclusions, based upon his own experiments and the former operations already referred to, as follows:

1. "Plaice tend to remain within the inshore waters during the period of immaturity."

2. "Whilst they may travel 20 miles or more in about a year, their movement is, as a rule, slow."

3. "In the areas investigated, their movement is in a definite direction, i.e. inwards along the south shore of the Frith of Forth in a westerly direction, then outwards and eastwards along the northern shore, and this general direction is continued round St Andrews Bay towards the north."

"These results," he remarks, "are in agreement with other investigations of the 'Garland' into the distribution of immature

[1] Petersen, *Danish Biol. Stat. Report*, 1894.

[2] First clearly pointed out in the *Trawling Report* of 1884.

plaice, and the position of the spawning-grounds, and they help to complete our knowledge of the cycle of life and movement of this important flat-fish."

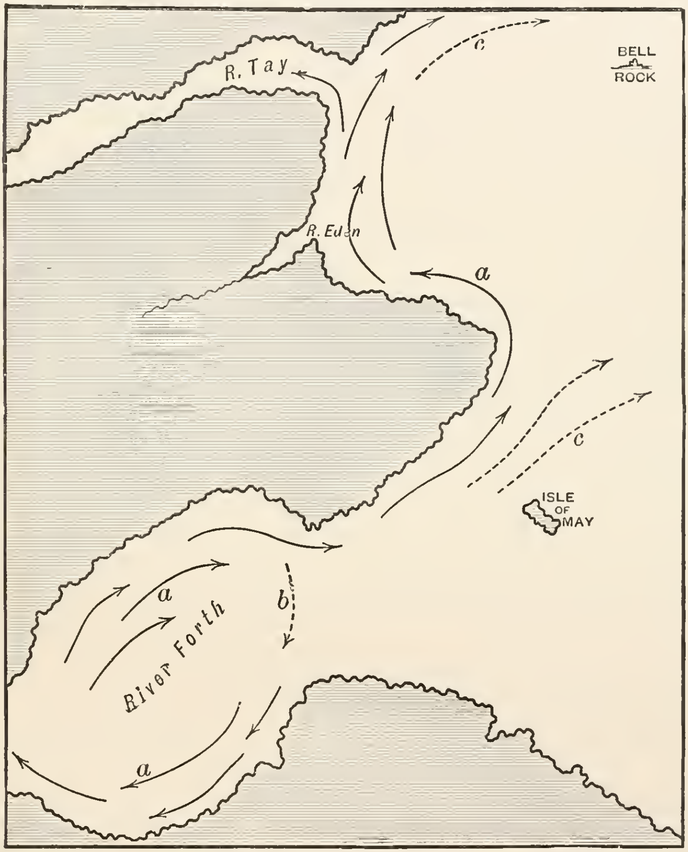


Fig. 39. Diagram showing the movement of plaice within St Andrews Bay and the Frith of Forth. *a* indicates the general direction of the movement; *b* represents a probable movement within the Frith of Forth; and *c* the movement offshore to the spawning-grounds. Dr Fulton, 11*th Ann. Rept. S. F. B.* p. 186.

"The spawning-grounds are situated off the mouth of the Forth and St Andrews Bay, the buoyant ova are floated inwards, and the immature fishes circulate in the shallower waters in the manner described, passing out to the spawning-grounds on approaching maturity: those from the Frith of Forth apparently chiefly by the channel between the Isle of May and the coast of Fife, and those from St Andrews Bay, reinforced to some extent by those from the Frith, probably moving out from the neighbourhood of the mouth of the Tay in the direction of the Bell Rock."

For what reason plaice set free near the south shore of the Frith of Forth should invariably migrate slowly but surely westwards, whilst others set free under similar circumstances on the north shore, should with equal precision travel eastwards round the Carr, across the sandy Bay of St Andrews and on northwards, we cannot possibly say. The problem is as difficult of solution as many another connected with animal migrations. It is possible that a migration such as this, occurring amongst the plaice of Danish waters, may account for the peculiar distribution of this fish, as given by Petersen.

Plaice appear to have very definite spawning-grounds, always well offshore. Taking the east coast of Scotland as an instance, in the Moray Frith district, 16 miles to seaward and in 20 fathoms of water is situated Smith Bank, at which immense numbers of large spawning plaice are found at the breeding-season, but it has yet to be proved that they do not occur there at other periods of the year. The same spot, which is rich in invertebrate life, is frequented by shoals of cod and haddock and at such a time the surface- and mid-waters contain vast numbers of the eggs of these species.

In the districts to the south of this, viz., about Montrose, the spawning plaice occur outwards so far as 25 miles offshore, but a little further south, off St Andrews Bay and the Frith of Forth, the spawning adults are again found rather nearer inshore: in the stations just outside the Frith of Forth are found great quantities of eggs of plaice in March and April, mingled with those of the haddock.

The position of these spawning-areas is doubtless determined by several factors, the exact bearing of each of which we are not yet in a position to appreciate, except that the tendencies of all the movements of the growing plaice bring them to the regions referred to. Dr Fulton[1] gives the results of experiments

[1] *S. F. B. Report*, 1895, p. 153.

to determine one of these factors, namely, the direction of marine currents. Large quantities of sealed bottles were discharged into the sea at the principal spawning-grounds and the resultant effect of various currents was indicated by the final destination of the bottles. The majority were washed ashore in a general easterly and south-easterly direction, which would lead us to suppose that from the spawning-grounds the pelagic eggs, and even the larvæ of the various fishes which frequent those areas, are slowly borne along towards the shore, all having a more or less southerly tendency.

We can now perhaps obtain an insight into the significance of the alongshore migration northwards of the young plaice, alluded to above. It is evident that were there no such compensating migration, the effect of the currents upon the eggs and early stages of the species would slowly but inevitably cause a transference of the species southwards. Further investigations, however, are necessary before definite conclusions can be drawn. Another important effect of the pelagic spawning-habit upon the distribution of the plaice is seen in the Danish seas. The low specific gravity of the waters of the Baltic opposes a barrier to the floating eggs of the plaice and its allies, and only recently have a few of these been found to occur, deep in the water, around Bornholme.

The life-history of the plaice thus resolves itself into a cycle of very definite limits, commencing with the pelagic egg floating over the spawning-grounds, the sport of wind and tide. Whilst the development of the embryo proceeds within, the egg is borne by the surface-currents towards the shore. The little larvæ continue, after hatching, to drift in the same direction till, after an average duration of six weeks or so, the post-larval fishes seek their way downwards through the mid-water to the bottom, and in doing so, turn upon the left side.

Close inshore, the little plaice, hidden in the sand or sandy mud, grow rapidly and prosper, in company to some extent with little flounders and dabs, and, as they become older they not only migrate alongshore but move seawards with increasing bulk till at last they complete their life-cycle by spawning and launching their thousands of offspring upon the sea of life.

The next point which demands our attention is the question of the rate of growth. The approximate growth-rate during the first year has been recently worked out by one of us according to the principles which are explained at length in the chapter on Rate of Growth, to which reference should be also made for the general remarks upon the growth-rate of pleuronectids. We may note that the average length of a plaice eight months old is three inches, and that this is increased to 4½ inches by the completion of the year, a six-inches plaice, further, being usually about 16 months old. Throughout the second summer the growth is very rapid and may perhaps result, at 1 year and 9 months, in an average length of some 10 to 11 inches.

There appears to be a consensus of opinion that by the following spring, namely in the third year, at an average length of 12 inches, the plaice arrives at maturity and reproduces its kind. Growth continues, however, and it is not uncommon to find plaice of 28 inches upon the east coast. According to Cunningham's observations, the plaice of the south coast of Britain are a smaller kind and reach maturity before attaining so great a length.

The Lemon-Dab. (*Pleuronectes microcephalus*, Donov.)

The pelagic eggs of this species first came under observation in August 1884, when ripe females were procured off the Forth during the Trawling Expeditions[1]. Considerable latitude, however, must be given in regard to the spawning-period, since in the south it is much earlier than in the north. Thus Couch says it is prepared for spawning early in February. Parnell, again, thought it shed its eggs during the month of April, after which it retires to rocky ground, where it generally remains till the commencement of the following year. He thus connected the fish with a migratory instinct during the spawning-season. Day gives May and June as the spawning-period. At Plymouth, Cunningham found pelagic eggs in March, April and May, as well as hatched the larvæ from artificially impregnated eggs. Holt found the eggs in April, May and June on the west coast of

[1] W. C. M., *Trawling Report*, p. 363.

Ireland. On the east coast of Scotland ripe forms are found from April to August, but so far as known there is no migration for the purpose of spawning. Ewart and Fulton conclude that the chief spawning-period is in June, and the same period is entered in the *Scandinavian Fishes* for Sweden, while Ehrenbaum for Heligoland gives the latter half of June and July. The large adults frequent rough ground near the Bell Rock, only the smaller forms occurring on the sandy ground in the Bay.

The eggs of the lemon-dab (Plate IV, fig. 15) are—in contrast with those of the plaice—comparatively small, having a diameter of ·053 in. or about 1·35 mm. Besides the ordinary pelagic characters they possess a slight sheen, a feature probably due to the peculiar structure of the surface of the capsule, which is minutely wrinkled, the ridges interdigitating with each other in a complex manner—somewhat like irregular basket-work. A series of prominent interlacing ridges, generally running obliquely into each other, covers the entire surface, while the interspaces are filled with rather closely arranged subordinate ridges (Plate IV, figs. 16 and 17). Under compression the stratum shows a somewhat irregular reticulation of pale streaks on the minutely punctured surface. Cunningham describes the surface as showing a number of fine raised ridges forming two systems of parallel lines which cover one another diagonally. Holt, again, states that, seen from above, the markings appear as a line to which the thickly-set punctures of the rest of the capsule do not extend, and is of opinion that the appearance is caused by sharp grooves indenting the surface of the capsule from a quarter to half its depth. The capsule in the lemon-dab is comparatively thick, and the development of the embryo, though visible, is not seen with that perfection of definition characteristic of more transparent forms. During development the wrinkled surface somewhat resembles morocco leather.

In the warmer months development is rapid. Thus in a series fertilized on the 8th July at 8 p.m., no pigment occurred till the fifth day (in Cunningham's it appeared on the fourth). The pale processes found during the fourth day upon the head, body and tail were, on the fifth, tinted gamboge-yellow by transmitted light. Moreover a few appeared on the yolk-sac. Some were hatched on the sixth, and the majority on the seventh day. Cunningham's examples hatched on the seventh or eighth day in April, so that those at St Andrews escaped somewhat earlier, as might have been expected in view of the temperature in July.

The larval lemon-dab (Plate XV, figs. 6 and 7) has a length of 3·5 to 4 mm., and is distinguished by the great length of the yolk-sac in proportion to its depth, and by the peculiar curvature of the head from above downward and forward. A considerable number of dull gamboge-yellow pigment-grains occur along the edges of the marginal fin both dorsally and ventrally —dorsally from the head to the tail, though not quite to the end of the latter; ventrally from the vent as far as a vertical line from the dorsal grains, and thus the series is short. The head and trunk are faintly yellowish from minute specks of the same pigment, and many occur on the yolk-sac. Under a moderate power of the microscope very finely ramose black pigment is observed in connection with the yellow on various parts of the body. The yellow pigment is not bright, indeed, in the egg it appears a dull greenish yellow.

On the third day the pigment on the marginal fin is light-yellow, while that of the trunk is dull greenish-yellow, probably from the greater development of black. The yolk has much diminished. The eyes are silvery, and the slender little fishes are active and sensitive. Next day the gills are fairly formed, and the mouth gapes, without any movement of the jaws, while the gullet seems to be open. The breast-fins are large and fan-like, and in swimming vibrate with great rapidity. As in the plaice under such abnormal conditions, the head is often directed downward so as to reach the bottom of the vessel. Five dull greenish-yellow spots occur, viz., the patch at the breast-fins, one just in front of the vent, and three in the region behind, yet the species is not readily seen in the water (Plate XV, fig. 8).

On complete absorption of the yolk (Plate XV, fig. 9) the early post-larval lemon-dab is characterised by great depth of the marginal fin, which still shows very bright canary-yellow touches of pigment. Dark pigment, however, has invaded the outer half of each spot, and occasionally it is even more generally developed. The five pigment-bars on the body are still diagnostic on the eighth day, and a stellate black corpuscle often appears at the base of each breast-fin, which shows a somewhat symmetrical series of fine embryonic rays with distinct intervals. The jaws are motionless, but widely apart, and the vent has also been open for some time. No blood-corpuscles are visible in the heart, but in Cunningham's examples pale corpuscles occurred on the fourth day. A marked incurvation of the ventral margin behind the head is present. They lived till the 11th day, and presented further a row of pigment-specks (which became conspicuous after immersion in spirit) along the ventral edge of the abdomen and clavicle.

The lemon-dab has thus a very hardy larva, almost as hardy as the plaice, and little difficulty would be encountered in hatching and rearing it for a considerable time under artificial circumstances. So hardy are the larvæ that a number lived about six days in a small glass cell 2 inches by $\frac{1}{2}$ inch deep, the water being filled up as it evaporated.

The early post-larval condition of the lemon-dab is probably that represented in 'Researches,' and in Plate XV, figs. 10 and 11, showing respectively four and five isolated patches of pigment along the dorsal and ventral margins of the muscle-plates. The body is exceeded in depth by the embryonic marginal fin which is yellowish, and the abdomen is prominent and slightly pigmented. Both sides are similarly coloured. The tail is abruptly narrowed, and the notochord proceeds straight outward, even when the fish is 8 mm. in length. The lower caudal rays and those immediately above are cartilaginous; all the others are membranous. The head and belly, at this time, appear disproportionally large since the trunk is long and slender. When the little fish reaches a little less than half-an-inch (Plate XV, fig. 12 and fig. 14, page 59) the marginal fin is appreciably narrower, while interspinous elements appear along the edge of the trunk. The outline now slants from the tail downward and forward so as to embrace the gut. Five pigment-patches occur along the dorsal line as before, besides some minute spots at the base of the tail. Inferiorly two touches are present on the abdominal margin, and one superiorly at the curve of the rectum; three others lie in front of the caudal pigment-spots. The abdominal patches are somewhat less distinct on the left side. A little black pigment is also present on the tip of the jaw, at the ventral edge of its angle, and on the prominent area below the breast-fins. The larval tail remains, while the inferior rays (forming the main part of the tail-fin) are well developed. Parasitic crustaceans (*Caligi*) are frequently attached to the anterior region.

At the length of 10·37 mm., as captured by Holt[1] off the west coast of Ireland, the general condition agrees with the foregoing.

When a little over half-an-inch (14 mm.) in length (Plate XV, fig. 13 and fig. 15, page 60), the greatest breadth of the fish, including the fins, is 7 mm. The left eye at this time appears, in profile, above the head, and is distinctly in advance of the right. The pigment-spots on the right and left sides are nearly the same,—though those on the right, perhaps, are more distinct,—four patches occurring along the dorsal and three along the ventral margin of the body. The touches on the abdomen are present, but somewhat altered by the growth of the tissues, and so with those on the ventral margin as well as the head. Pigment-specks persist at the base of the tail. The body is now proportionally broader. In specimens a little (2 or 3 mm.) longer similar features as regards pigment and other points occur, but the left eye is mounting the head, and the ventral fins appear as minute buds. The marginal fins are still infested by young parasitic crustaceans (*Caligi*). The foregoing specimens were generally procured E. or S. E. of the Island of May in water varying from 18 to 29 fathoms, the mid-water net being floated about 4 fathoms above the bottom. They are however got in considerable numbers, and ranging from 8 to 18 mm., towards the end of October in the Moray Frith, showing that the spawning-season of the species, as observed in 1884, is continued late into the autumn. From the position of the eyes and the occurrence

[1] *Op. cit.*, p. 90, Pl. 15. f. 120.

of the young *Caligi* they would seem to swim on edge up to this size. The longest (18 mm.) has the left eye well up on the ridge, but the pupil looks obliquely upwards rather than laterally. The young *Caligi*, which in some are four or five in number on each side, are chiefly fixed in front of the breast-fins, on the cheeks and throat, and some of the smaller fishes (10 to 11 mm.) have the largest parasites. In one or two they occur at the base of the tail. In such forms the pigment is nearly equally developed on both sides, indeed in some more pigment is found on the left (the future white side) than on the right —a feature observed in other species.

On comparing the foregoing, which were at first thought to pertain to the craigfluke or "witch" of the Scottish fishermen, with the young of that species as now known, it is seen that the body of the latter is much narrower, and the shape of the head different.

The next stage is observed in a specimen 25 mm. long (Plate XV, fig. 14) procured at the surface by the Garland, 7th May, 1890, the Bass, W. by N., ten miles. At this stage it is distinguished from the dab by the less elliptical outline, the body being thick and somewhat blunt anteriorly and less tapered posteriorly. The eyes are smaller, the head more rounded, and the mouth less. The right side shows, instead of its minutely speckled condition in a dab of the same or even a less size, traces of four distinct marginal touches dorsally, with a minute fifth point. Ventrally are corresponding marginal touches, the fifth being at the ventral fins, while in front of these are one or two additional specks on the edge of the throat and snout. On the left side traces of similar touches yet remain, but they are much less distinct. The left eye is prominent on the ridge, and looks obliquely upward and to the left when the fish is placed on its edge. At this stage also the young crustacean parasites (*Caligi*) are present—one in the figure being attached to the right side near the tail. These young lemon-dabs therefore seem to swim on edge for a considerable period, for Holt has since found a specimen 27 mm. long off the Skelligs on the west coast of Ireland in August, which agrees in most respects with the foregoing, and his description and figure are given with great accuracy and clearness[1]. As Holt points out, all these examples have been procured at a considerable distance from land, and it is only when about 2 inches in length that they approach the shore.

A summary of our knowledge of the older stages has been given by Mr H. C. Williamson[2], and he appends a table of sizes from 9·7 mm. to 260 mm. (more than 10 inches), with approximate ages, from which it would appear that several years must elapse before the lemon-dab attains full size. Moreover, though Holt found specimens of 2 inches and upwards close inshore on the east coast of England, they are by no means common in Scotch waters, the sizes procured in the Trawling Expeditions ranging from 5 to 10 inches, and some of these occurred in St Andrews Bay. Cunningham's observations further show that the inshore forms off the south-east coast range from 3 to 5 inches.

The adult fish is comparatively valuable, and in certain parts of the east coast is by no means common. The younger forms, it is true, are not unfrequently caught in the Bay of St Andrews, but the adults haunt the somewhat rough grounds near the Bell Rock, for which their dexterity in passing along rocky surfaces and up perpendicular ledges peculiarly fits them. A dozen may be caught on a single line baited with mussels in a night, while, again, for months none will occur. Parnell states that it is considered unwholesome in April, May and June, but does not seem to connect this condition with the spawning-season. No indication of this has been observed.

Holt found the smallest ripe female to be 8 inches, and Cunningham the smallest ripe male 6·4.

THE WITCH OR POLE-DAB. (*Pleuronectes cynoglossus*, L.)

The "witch" is a fish not uncommon on the muddy ground south east of the Isle of May, in the Moray Frith, and elsewhere on the eastern shores of Scotland, and is still more abundant in

[1] *Sc. Trans. R. Dub. Soc.* vol. v. (II *se.*) p. 91, Pl. xv, fig. 121, 1893.

[2] *Eleventh Annual Report, Fishery Board*, p. 271 *et seq.* 1893.

many of the western areas, as near Inverary, Loch Fyne. Prof. Herdman[1], Mr Cunningham and Mr Holt have had an opportunity of examining the eggs, which are shed from April to July. In Scandinavian waters the spawning-season is later. They are transparent pelagic eggs—measuring from 1·15 to 1·19 mm. The capsule exhibits faint striæ, first mentioned by Holt, though Cunningham thought the capsule thicker than in most of the flounder-tribe. Development took place with moderate rapidity, and hatching ensued in 6 days. Pigment appears to be slightly developed in the egg. The larval fish (Plate XVI, fig. 2) is about 3·9 mm. or a little more in length, devoid of pigment in the eye but with a number of minute yellowish specks scattered along the sides and on the head as well as over the yolk and marginal fins. Black pigment appears on the head, trunk and caudal region within 48 hours and the body has now considerably elongated (5·11 mm.). Moreover the pigment has been grouped into three bars in the post-anal region, as in the lemon-dab, besides one near the vent, and another about the breast-fin, and, probably from the effect of the black, the bars appear greenish by transmitted light. Pigment also occurs in the eyes. The first gill-cleft is open, and indications of four others are behind. The mouth opens about the fourth or fifth day, and the yolk has almost disappeared. Ten days after hatching, according to Holt, though the dimensions of the early post-larval fish have not much increased (5·57 mm.), the eyes are black with a bluish lustre, the lower jaw is freely moveable, the gill-arches are simple, the otocysts spacious and near the eyes, the breast-fins are very large and the clavicle well-marked. A ventral patch of black chromatophores has appeared mid-way between each post-anal pigment-bar; the bar at the pectorals is less distinct; pigment occurs on the lower jaw and anterior ventral surface. The colour of the pigment is now orange by transmitted light, except on the median fins, where it is brownish.

On the 19th August, young specimens 42 mm. ($1\frac{3}{4}$ inch) in length were trawled in 80 fathoms off the Skelligs (Plate XVI, fig. 3). They were at first considered to be young soles, and

[1] *Report Lancashire Fisheries Lab.* 1897, p. 13, Pls. 2 and 3.

were published as such in *Nature*[1]. Mr Holt, however, obtained examples and brought them to St Andrews, where their true nature was explained. The remarkable proportional length of the narrow body is a diagnostic feature. The fin-formula as given by Holt is D. 105, A. 89, C. 23, a result corresponding with the adult; in other species it is not unusual for the young to have a larger number of rays in the caudal. The lower jaw is not longer than the upper and has a well-marked prominence at the tip. The vesicular structures (foveæ) are apparent below the head (on the blind side). Scales are present on the tail-peduncle. In the preserved examples the black pigment alone remains scattered all over the ocular side. There are two small and three large black patches on the interspinous region dorsally, three large patches corresponding to the latter three in the ventral region, and indications of connecting bands in the middle of the body. A patch of black is found on the distal part of the breast-fin, patches occur on the pelvic fin, tail, extremity of the clavicle and ventral edge of the abdomen. Holt estimates the age of these at 4 or 6 months, and he is probably right.

Older stages about 5 to 7 inches in length were trawled at 144 fathoms in July, and the characters are adult. These are probably a year old. In the Trawling Expeditions no very young witches were observed, the smallest having a length of $7\frac{3}{8}$ inches. They were most numerous in the Moray Frith.

An outline of a young specimen at the preceding stage (when it takes to the bottom) is given in Plate XIV, fig. 14—after Petersen.

THE DAB[2]. (*Pleuronectes limanda*, L.)

This little pleuronectid, the smallest of the genus, also has the smallest egg (Plate IV, fig. 18), although that of the flounder is only slightly larger. The average diameter is about ·033 of an inch (0·70 mm., 0·75 mm. Canu[2], 0·78 mm. Holt),

[1] *Nature*, Vol. 42, p. 520, and correction ibid. Vol. 43, p. 56.

[2] The eggs and larvæ of many Teleosteans have been described by Dr Canu in the *Annales de la Station Aquicole*, Boulogne, 1893. It is unnecessary to refer to those which only corroborate previous observations.

which will be seen to be only $\frac{1}{200}$ inch less than the diameter of the flounder's egg, a difference which is well within the limits of variation in the size of pelagic eggs. Neither egg having an oil-globule it is often hard to distinguish them at an early stage.

The spawning-period commences in the month of March (Canu says February for the coast of France, and Smitt gives April to June in Sweden[1]), is at its height in April, and may continue to the middle of June. The spawning dab carries a smaller number of eggs than most pleuronectids and is one of the least prolific of the flat-fishes. The male is, as a rule, rather smaller than the female, though disparity of size between the sexes is not so marked as in the case of the long-rough dab: the males are also in a marked minority. In its spawning-season this fish appears mostly to be found beyond the three-mile limit, but spawning females undoubtedly do occur within the territorial waters, so that the dab does not exhibit such a strongly marked migratory instinct as, for instance, the plaice. The occurrence of dabs of all sizes far from land, as pointed out in the Trawling Report of 1884, shows that many are reared on the ground inhabited by their parents. In respect to its spawning, the dab may perhaps be regarded as intermediate in character between the plaice and the flounder. The plaice migrates well offshore in the adult condition, whilst the dab does not do so to such an extent (spawning dabs are found in the three-mile limit, but spawning plaice are not), whilst the flounders migrate only to such an extent as to leave the fresh or brackish water and deposit their eggs at a safe distance from the shore.

A series at St Andrews Laboratory were fertilized at the end of April and the larvæ, measuring a little over 2 mm., emerged in twelve days, whilst others again in early June were hatched in seven days, as Canu recently found them do on the French coast in March and April.

Following out the stages in the first series, bright yellow round chromatophores make their appearance on the seventh day, scattered over the head dorsally and upon the tail. All over the yolk-surface are a number of fine strands, giving

[1] *Scand. Fishes*, 390.

it a reticulated aspect. The black pigment is later in its appearance than the yellow, and consists of a few scattered stellate spots. The lemon-yellow markings somewhat differ from the chrome-yellow of the flounder, forming more distinct lines in the dorso-lateral region. There are two pairs of these longitudinal rows on the trunk, and a few days later a line on the dorsal part of the marginal fin. This disposition of the yellow pigment is seen, even more distinctly, in the larva of 11 days (Plate XVI, fig. 4). By this date the eyes are very clearly indicated by black pigment and by a greenish metallic lustre.

The larva, hatched on the twelfth day, is very small, being only from $\frac{1}{18}$ inch to 2·6 mm. in length (Cunningham and Ehrenbaum), and is at once easily recognised by its distinctive lemon-yellow colour arranged in bands as described above. Of all pleuronectids, the larval flounder, when just hatched, most resembles the dab, though one of us[1] has described an unknown larva (Plate XVI, fig. 1), hatched in the laboratory which also very much resembles the latter.

The larval dab continues to develop its yellow pigment in longitudinal bars, whereas the young flounder changes its coloration considerably as described later. The crescent-like arrangement of the chromatophores in the dabs reared in 1886 in the St Andrews laboratory are probably due to free exposure to light. Dr Ehrenbaum, who carefully describes and figures the early post-larval forms, has not noticed this in his examples, and they have not been seen in free forms. The young flounder of 13 days (Plate XVII, fig. 2) and the young dab of 11 days (Plate XVI, fig. 4) can therefore at once be distinguished, the differences being sufficiently striking in a superficial comparison of the two forms. A young plaice of the same age is also clearly differentiated by its large size and the dorsal and ventral black rows with a sparse yellow patch (see plaice).

A dab in which the body has considerably increased in depth while the eyes are still lateral is shown in Plate XVI, fig. 5, in a fresh though somewhat altered condition.

[1] W. C. M., 11*th Report S. F. B.*, p. 243, Pl. X, f. 1—5.

In young plaice and dabs with the eyes in the pelagic condition, that is on each side, the distribution of the black pigment dorsally and ventrally is diagnostic, while the dorsum, in the earlier stages, shows only a limited series of black specks, which at a later stage aggregate into two or three dorsal patches; the ventral edge is much more boldly pigmented with black. A black touch occurs at the angle of the mandible on each side, and, behind, a narrow spear-head of black runs to the clavicular region and ceases. Then a single median line of black extends rather behind the middle of the abdomen, which is speckled with black. Black chromatophores are present at the vent, and a well-marked double series extends to the tail—at a later stage also aggregating into the ventral touches. Other marked touches occur along the abdominal roof and on the cheeks. It is a curious feature also that the sides (dorsal and ventral) of the larval tail are mapped out by lines of black chromatophores, *e.g.* when about 8·9 mm. in length. While the eyes are silvery in lateral view—from the dorsum they are of a fine iridescent green like a diamond beetle's wing.

The smaller forms of this species and also of plaice and flounders often become the prey of little jelly-fishes (fig. 11, page 56).

A warm day (*e.g.* 11 May, 1896) brings the young plaice, dabs and flounders to the surface in numbers—apparently after their food, yet their eyes are on the right. They are very translucent, and are about 18 mm. in length.

Importance is attached to the comparison of these three species in their earliest stages, and to their diagnostic features, because the young fishes after assuming a habitat in sandy and muddy shallows are exceedingly hard to distinguish specifically. In fact, at a certain age it is probable that, in spirit, there is no one feature by which we can with absolute certainty pronounce a given young pleuronectid to be a dab or a plaice. A distinction of approximate value is found in the fact that although a dab, *e.g.* of $\frac{1}{2}$ inch length (Plate XVI, fig. 6), is older than a plaice of the same length, it is thinner and more elongated. Holt states that at the same total length, "the rotation of the eyes is less complete in the dab than in the plaice, the height of the body is relatively greater in the plaice than in the dab, and the size of the eye, as compared with that of the head, is larger in the dab than in the plaice. Moreover, a general pigmentation of the ocular side is assumed by the young plaice at a smaller size than in the case of the young dab."

Fig. 6, Pl. XVI, represents a dab of a length of 12·25 mm. or about the same length as Plate XV, fig. 3, of a young plaice, so that the general appearance of the two may be easily compared. One of the most marked characters is the forward extension of the dorsal fin on to the head in the plaice and the absence of this in the dab, so that there is a gap in the latter between the dorsal fin and the eyes. This and other features point to the fact that the dab, although a smaller fish, takes a longer time, or at least attains a greater size, before completing metamorphosis. The young dab here figured and referred to is in its structural characters at nearly the same stage as that of the 10 mm. plaice, Plate XV, fig. 2. We may note that the general arrangement of the black pigment closely resembles that described for the plaice, and the gradual increase of the same is noticed, the dorsal and anal fin-rays being later marked out with black spots. The characteristic pleuronectid succession of dorsal, anal and caudal bars or patches may be noticed.

In Plate XVI, fig. 7, is shown a later stage at 15·25 mm. in length. Here the brownish pigment has appeared and shows the same tendency as in the plaice to aggregate into patches which are also partly arranged in transverse bands corresponding to those of the black pigment-patches. A little later than this, the brown pigment no doubt becomes diffuse as in the plaice.

In the young plaice, the brown pigment first appeared at a length of about 12·87 mm. (Plate XV, fig. 3), and such a form is in other features at about the same stage as that of the young dab under consideration.

An observation of Petersen's is not without interest here. He remarks " while the pelagic stage of the plaice in our seas is generally ended with a length of 10·11 mm., that of the flounder with 8 mm., the pelagic state of the common dab, though it belongs to a smaller species, does not seem to be at an end till the fish has reached a length of 12 to 13 mm." He also found that the fin-rays of young dabs of 14 to 46 mm. varied from 73 to 65 in the dorsal fin, and 55 to 51 in the anal fin. From this and the observations of other workers, it is evident that the number of fin-rays is a doubtfully distinctive feature between plaice and dabs, at any stage, though, as will be seen later, it forms a ready method of separating these two species from the flounder on the one hand and from the witch and lemon-dab on the other.

We may note in Plate XVI, fig. 7, the appearance of the lateral line with the anterior curve characteristic of the adult. A detailed description of the pigmentation is unnecessary with the figure before us.

Later, the young plaice develop the adult tubercles upon the ridge between the eyes, and later still the dorsal and anal row of tubercles at the base of the fin-rays distinguish the flounder, and the curved lateral line indicates the dab. The number of fin-rays appears to increase with the age of the young fish up to the number found in the adult.

Little dabs of about 1 inch in length are found on St Andrews sands and in the Forth in January and February, and these, even when the lateral line is not visible, differ from young flounders in their more elongated outline and larger eyes, features at once recognised by a cursory inspection.

The post-larval forms have yet to be exhaustively distinguished from those of the flounder, and perhaps other pleuronectids, but the figures given probably indicate their general characters.

As regards the rate of growth of the dab there is a good deal of uncertainty concerning the young stages. The dab appears, according to the work of Mr Williamson, to have a curve of growth closely similar to that of the lemon-dab, though the former seems to grow more rapidly during the first year.

Young dabs are found in the estuary of the Thames in October and are caught in the shrimp-trawls. They vary from 1¼ inch to 3 inches in length. The smallest of these must be at least $3\frac{1}{2}$ months old and the largest are probably 8 or 9 months. Dabs and lemon-dabs of six inches or thereabout may be put down as having attained the age of two years. As regards later growth Dr Fulton has conducted a series of experiments upon young dabs confined in a tank. One specimen ($8\frac{5}{8}$ inch) grew $2\frac{1}{2}$ inches in length and increased from 4 oz. to $10\frac{1}{4}$ oz. in weight in 16 months: another ($7\frac{1}{8}$ inch long) grew $1\frac{7}{8}$ inches and more than doubled its weight: yet another ($10\frac{7}{8}$ inches) grew to $12\frac{1}{2}$ inches in length in the same period of time and increased in weight from 8 oz. to $14\frac{1}{4}$ oz. Young plaice under exactly the same conditions showed a far slower rate of growth both in weight and size.

The smallest of the above dabs spawned when 10 inches long, but apparently not till then, so that it appears that the dab occasionally does not become sexually mature till the third year.

Cunningham has made similar experiments with dabs under domestication in Plymouth Laboratory. On capture in September and October, 1891, they were from $1\frac{3}{5}$ to $2\frac{3}{5}$ inch, and by March, 1892, they were from 2 to $4\frac{4}{5}$ inches. A year afterwards, at which time less than half of them survived, the remainder measured from $4\frac{1}{4}$ to $8\frac{1}{4}$ inches.

Sundevall[1] considered that the dab took four or five years to attain its ordinary size of from 20 to 25 cm. (9—10 inches). He took specimens from 34 to 133 mm. on the 19th May, and thought that the first was a year old; that of 94 mm. a year older; both it and specimens 133 mm. long being in their third year.

THE FLOUNDER. (*Pleuronectes flesus*, L.)

Although a much smaller fish than the plaice the flounder is a very near ally, and so resembles it in structure that a casual observer might conclude that the life-histories of the two were closely similar. It is a point especially fraught with interest to find therefore that all the known facts in relation to the two species tend to emphasize the conclusion that they are widely separated in their habits and their migrations—as

[1] *Scand. Fishes*, 390.

will be seen by a careful comparison of the data given below with the preceding account of the plaice.

The flounder is peculiar in that it appears to arrive at sexual maturity whilst still very small and, one would naturally conclude, very young. Artificial fertilization has been successfully effected at St Andrews between a female 7 inches long and a male $4\frac{1}{2}$ inches long; and we must add to this that the male in this species, in accordance with the general rule, is smaller than the female, so that we may reasonably suppose that many male flounders come to sexual maturity when less than $4\frac{1}{2}$ inches in length. The mature female carries a greater number of eggs than any other pleuronectid, so far as is known, averaging from 400,000 to 1,200,000. The eggs are also very small, about ·038 inch (·95 mm.) diameter, are pelagic and without an oil-globule.

The size of the eggs and the great number discharged by the female, or in other words the 'exceptional fecundity,' may possibly be factors in causing the flounder to be an exception to all other pleuronectids in that the females are less numerous than the males. This preponderance in numbers of the male sex is usually found only in species which have a demersal spawning-habit, whereas the opposite relation holds amongst those having pelagic eggs. These facts are sometimes explained by the lesser chances of fertilization amongst demersal eggs, because they are isolated in masses and the spermatozoa are extruded directly upon them by the males.

The disparity in size between the sexes of the flounder is also a feature found in all the pleuronectids or flat-fishes, the culminating point in this character being reached by the long-rough dab, in which fish the female is often three times the length of the male.

The eggs of the flounder (fig. 2, p. 31) are found in greatest abundance during the months of March, April, May and June, but they may also occur as early as February and as late as mid-July.

In the Trawling Report of 1884 it was shown that spawning flounders did not occur on the E. coast of Scotland at a greater depth than 30 fathoms, and that, in St Andrews Bay, the majority spawned in water of from $4\frac{1}{2}$ to $10\frac{1}{2}$ fathoms. As the adults are essentially estuarine in their habits, there is a migration in connection with spawning from the fresh or brackish water to the areas a few miles offshore where spawning is effected.

Again, it is said, there is a migration of flounders into deeper water during the cold of winter, which is of course not connected with the spawning function (Buckland). Further observations, however, are needed on this head, for our own do not bear them out.

As in the case of the plaice there have been some curious mistakes made concerning the eggs of the flounder. Buckland states that the masses of eggs belonging to certain worms, found between tidemarks, were believed by the fishermen of Morecambe Bay to be those of the flounder, and Mr Cunningham observes that the fishermen of Essex also considered them to be the eggs of the plaice, as late as 1893[1].

Flounders are peculiarly susceptible to a diseased condition, consisting of whitish masses of a tumour-like nature. These have been construed by the fishermen of some districts as the eggs of the flounder, adhering to the skin of the parent. They have been studied at St Andrews[2] by several observers, and one of these (Mr Sandeman) claimed that their inner structure resembled that of certain types of eggs, although there was of course no possibility of their being those of the flounder, as these had already been fertilized and described by Dr Malm, of Göteborg, in 1868, and the early stages of development fully worked out in 1884 at the St Andrews Marine Laboratory.

The egg hatches eleven days after fertilization in March, but in the warmer month of June the period of incubation is reduced to about six days. In the former case, the development of the embryo proceeds till the fifth day without any sign of pigment or opacity. By this time however a number of yellowish-brown spots make their appearance, a

[1] *Marketable Marine Fishes*, 1896, p. 230.

[2] See W. C. M. *Ann. Nat. Hist.* June, 1885, and *3rd Rept. S. F. B.*, p. 66, 1885.

colour at once distinguishing this species, even at so early a stage, from the embryonic dab and other pleuronectids with their bright yellow spots. About 24 hours later, large stellate black chromatophores appear, they and the brown spots having a similar distribution. They are irregularly scattered over the dorsal region, being most numerous just on each side of the middle line and on each lateral line, thus showing a tendency to form two pairs of longitudinal rows, two dorsal and two lateral.

A day after this, the colours have become pronounced and are more definitely arranged. A distinct row of black stellate spots runs down the mid-dorsal line, and on each side of it is a well-marked row of brownish-yellow spots interspersed with a few black ones.

This arrangement alters very little from now till the eleventh day when the larva emerges from its imprisonment. Plate XVII, fig. 1, shows the newly-hatched larva, which is very small compared with the larval plaice, viz. 2·3 to 3 mm. in length. Amongst other features it may be noted that no chromatophores occur upon the yolk-sac; that the yellowish-brown pigment tends to form a patch of colour just above the vent and another half-way down the tail. A somewhat symmetrical disposition occurs upon the head. The black pigment is intermingled with the coloured. Apart from the pigmentation, the larva is perfectly translucent and is very active.

About the thirteenth day the greater part of the yolk has been absorbed, and the larva has undergone important structural modifications. The lower jaw grows forward and projects in front of the snout, and the marginal fin becomes very broad and deep—causing the body to assume the typical pleuronectid shape while it is still perfectly symmetrical. Thus although the pleuronectid larvæ can be readily distinguished at this stage from gadoids by the great depth of body and marginal fin, yet this character is only preparatory to the later changes which result in the peculiar asymmetry of the flat-fish. The general coloration of the little flounder of this age is diagnostic and may be briefly described (Plate XVII, fig. 2). Both the brownish-yellow and the black spots are stellate and are aggregated into a conspicuous transverse band extending across the trunk and both marginal fins about one-half of the distance from head to tail. A few scattered black stars are seen upon the tail, whilst others, both black and yellow, are distributed over the neck and abdominal region, the yellow only being found upon the head. The pigment of the eyes is late in appearing in this species, and shortly after this the characteristic silvery sheen is observable.

With further development, the remainder of the yolk is absorbed, and the body deepens still more with the commencement of the post-larval stage (Plate XVII, fig. 3). The broad marginal fins are marked at their outer borders by black touches of pigment, a small yellow spot usually accompanying each black mass. There are usually eight of these touches upon the dorsal fin and four on the ventral. Minute yellow dots are also scattered on the surface of both marginal fins. These peculiar little touches of pigment arranged in pairs dorsally and ventrally along the outer edge of the marginal fins are remarkably characteristic of the pleuronectid family, as is also the early appearance of both black and yellowish pigment. Dr Ehrenbaum[1] gives an account, with figures, of two stages closely succeeding that just mentioned, and they lead to the subsequent stages to be described, so that the series is complete. The spread of the pigments over the deepening marginal fin dorsally and ventrally is very characteristic. The post-larval flounders are still pelagic but have commenced their migration from the surface through the mid-water to the bottom. Though very deep in the body they still swim with the dorsal fin uppermost, and only subsequent to this stage does the movement to one side take place. They are stated by Petersen[2] to forsake the pelagic state at 8 mm. length. Holt[3] found a young flounder of 10 mm. still in the pelagic habitat ($\frac{1}{2}$ to 2 fathoms), so that Petersen's remark must not be taken as a generalisation. The young flounders (Plate XVI, figs. 8 and 9, and Plate XVII, fig. 4) when they reach the bottom can be distinguished from

[1] *Op. cit.* 1896.

[2] *Rept. Danish Biol. Stat.*, 1894.

[3] Holt, *Trans. Dublin Royal Soc.*, p. 79.

the young dabs and plaice by the smaller number of fin-rays. Petersen gives in flounders from 8 mm. to 33 mm. long, 49 to 65 fin rays in the dorsal fin and 33 to 43 in the anal fin. In addition to this the young flounder is always in a more advanced structural condition than young plaice or dabs of the same size. More pigment is present and the metamorphosis has proceeded further. Later, the appearance of the dorsal and anal rows of tubercles at the base of the fin-rays and at the anterior end of the lateral line at once distinguish the flounder.

In the month of April, these little fishes may be caught in St Andrews Bay by the mid-water tow-net and many of them present stages in the transformation to the adult one-sidedness; thus in some the left eye may have only moved a little forward on its own side, in others it may have reached the median ridge on the top of the head, whilst in a third series the eye may have completed its journey and be found on the right side. Together with this movement of the eye, the fish has gradually assumed the habit of moving on its left side, so that at the end of the curious transformation it is admirably adapted for its new habit at the sandy or muddy bottom of the sea-shore.

A few weeks later the little flounders are to be found along the shore-line, especially at the mouths of streams and rivers, shewing thus early a predilection for fresh or brackish water, which remains throughout life. They are beautifully transparent (Plate XVII, fig. 5) and extremely hard to detect when not in motion. In size, they average from a half to two-thirds of an inch in length and when exposed to light in captivity they rapidly lose their transparency by the development of variously tinted pigment of the skin (Plate XVII, figs. 6, 7 and 8). In the grey mud of the rock-pools they disport themselves in company with young plaice of the same size. These are closely similar but, the plaice being a larger fish, a young form of the same size as the young flounder is distinguishable by 'younger' characters—thus the displacement of the eyes is less complete, the body is broader and thinner and the ventral fins rudimentary. We may here quote an observation made some years ago: "The sparrow has been noticed to be destructive to young flounders in the harbour. At ebb-tide in May this bird watches by the side of the tiny pools in the mud, and seizes a young flounder whose prominent glistening eyes (minute though they be) are sufficient to betray it—although its almost transparent body is immersed in the sand. It then lays it on the side of the pool and watches for another, and so on until it has a fair mouthful to carry to its young[1]."

Throughout the summer shoals of these little flounders are found in the sandy shallows. Some of them attain a length of 3 inches by the end of June, and may have a maximum age of 4 months, but may be less, while in July they may be as long as 4 inches. By the autumn many may attain a length of as much as 3½ inches. In the tanks at Plymouth Cunningham found they grew from ½ an inch to 3 inches in 3½ months. Before this time the characters of the adult are assumed and with them, no doubt, the adult habitat, but the subsequent history is little known, though in the tanks of the Plymouth Laboratory they grew to 7 inches in 18 months.

The flounder is undoubtedly more shore-loving than the plaice, and is often found far up the estuaries of rivers, apparently being in no way inconvenienced by the change in the salinity of the water. Essentially a dweller in mud or sand it buries itself till only its keen little eyes are visible, the general colour of the body completely harmonising with its environment. Its love of fresh water is remarkable, and one cannot help conjecturing as to how far the flounder would become adapted to a river-life had nature not placed a barrier in its way in the form of a pelagic spawning-habit. It is evident that no fish with freely floating eggs can become of completely fresh-water habitat for at every generation the helpless embryos would be borne backwards to their original home in the sea, even assuming that the difficulty with regard to specific gravity were overcome. It is not therefore surprising to find that all fresh-water fishes, as far as is known, have demersal eggs. (Cf. Shad.) As regards the rate of growth, more data are required before pronouncing with any degree of certainty upon the length attained by a young

[1] W. C. M. *6th S. F. B. Rept.*, p. 274.

flounder at the end of its first year. It is probable that the average first-year flounder will be about 4—5 inches in length, perhaps a little less than the one-year plaice.

The flounder, therefore, commences life in the surface-water of the sea, at a distance varying roughly from 1 to perhaps 8 or 9 miles from shore. As development proceeds it is drifted shorewards, until the post-larval form, having effected, whilst in mid-water, its change to the left side, commences to acquire the adult characters and takes to the bottom. Larval and post-larval plaice, drifting in from the spawning areas, out beyond those of the flounder, follow the same course and shortly after the transformation is complete the little flounders and plaice keep company in the rock-pools and shallows of the shore. It is at this stage, when the two species live somewhat the same life, with the same food and enemies, that the differences in their structure are hardest to make out. As growth in size proceeds they part company, each species taking its own particular direction. The little plaice move slowly seawards over the sandy flats and eventually pass the rest of their life in deeper water offshore, whilst the young flounders seek out the estuaries and mouth of rivers, and revelling in the mud and sand and the abundance of food hidden therein, they follow up the course of the rivers inland until, as in the Severn, impeded by locks and other barriers. On the attainment of maturity, they migrate out to the sea to discharge the duty of reproduction.

The Sole. (*Solea vulgaris*, Quensel.)

The egg of the sole has been known on the east coast of Scotland since the Trawling Expeditions of 1884, when an adult with ripe eggs was captured in August ten miles from land (off St Abbs Head). They floated buoyantly, but, no male having been obtained, their development could not be followed. The spawning-period of the sole off the east coast of Scotland stretches from the middle of April, the eggs then appearing in St Andrews Bay, till the beginning of August, as just mentioned, a period of about four months. Dr Raffaele next figured and described the eggs of two forms of sole, both of which approached that of the British species in structure, and one nearly in size. Prof. Marion procured the eggs off Marseilles in February. Mr J. T. Cunningham[1] gives March, April and May for the South. Ehrenbaum[2], who furnishes an excellent summary of our knowledge of the life-history of the sole, gives May and June as the chief spawning months, more rarely July. The egg is so characteristic that there can be no doubt in regard to its identification (Plate IV, figs. 8 and 9). The diameter ranges from ·045 inch to ·051 inch, or 1·143 to 1·295 mm. It is transparent and has a more or less complete ring of minute oil-globules in groups, and of a yellowish white colour from refraction of the light, for when viewed by transmitted light they are faintly straw-coloured. Besides the ring, a few small groups occur here and there at other parts. Under a lens, indeed, the egg appears to be flecked with yellowish-white pigment. When floating, the ring of oil-globules is superior, as in other instances, the disc being inferior. The large oil-globules have a diameter of ·0015 inch, while the smaller measure ·0004 inch. The capsule is somewhat thick and tough, so that considerable force is necessary to rupture it; occasionally it is slightly undulated. It is also very distinctly punctured, even more so than in the egg of the plaice. A curious abnormality occurred in one example, since the surface of the capsule showed a series of flattened disc-like processes so as to give it a rough or scabrous appearance. The yolk presents on its surface a series of vesicles which project in the early condition beyond the edge of the protoplasm (periblast) round the disc, and at a later stage are seen round the greater part of the yolk, except at the tail of the embryo. The eggs develop with moderate rapidity, so that those which

[1] This author appears to be unaware that in many of the sandy bays of the east coast of Scotland the sole is not uncommon, if the proper means be taken to secure it. Thus, for example, in former years one or two pairs of good soles were often got in St Andrews Bay in trawling by night, and in the deeper water beyond they are occasionally captured by the hook. Both eggs and adults have been more frequently met with since about 500 from the northern coast of England were placed in the Bay.

[2] *Op. cit.* p. 307.

presented the condition shown in Plate IV, fig. 9, hatched on the fourth day. When the embryo is formed pigment develops rapidly on the head and on the surface of the yolk. The tint is dull whitish or faintly yellowish, and thus in marked contrast to the yellow of such species as the gurnard.

When the embryo is fairly formed the groups of oil-globules change their position, most occurring along the under-surface of the developing fish, as in the egg of a sole described by Raffaele. In connection with these oil-globules it may be mentioned that they comport themselves differently from the single globule in other eggs, such as those of the gurnard. They do not move freely, as far as observed, at any period of development, but retain their positions during the motions of the ovum. Their relation to the protoplasmic covering of the yolk must therefore differ materially from that in the gurnard. Raffaele considers they are imbedded in that portion of this layer which divides the vitelline segments, and move with the latter. They certainly advance with the rim, but their subsequent arrangement under the developing embryo is a remarkable feature, indicating, indeed, besides concrescence, the probability that something like a streaming of the protoplasm of this layer takes place about the closure of the blastopore, so as to carry the globules under the developing embryo. They are, on the other hand, set free later in a dead egg, so that they pass through the yolk as in the gurnard and other forms.

The eggs of the sole are comparatively hardy, and the larval sole is no less so. On its escape from the capsule (Plate XVIII, fig. 2) it is about 3 mm. in length and the entire body, yolk-sac, and marginal fin are minutely speckled with opaque yellowish-white pigment. This is arranged in interrupted touches on the body and marginal fin both dorsally and ventrally behind the yolk-sac, so that the pleuronectid character is early indicated. Moreover, the presence of pigment at the extreme margin of the fin gives great apparent depth to the body of the little fish. The yolk-sac is comparatively large and globular, sustaining the animal readily in the water—either in the inverted position or with the tail downward. At first it progresses indifferently from the great size of the yolk, rolling over or advancing in a screw-like manner. While in lateral view the yolk-sac is somewhat ovoid, it is quite circular when seen either from the front or rear. This larva is one of the most active and restless of the group—seldom remaining quiescent more than a few seconds. No pigment other than the superficial chromatophores exists in the eyes. The oil-globules form two main groups, one series running from the heart obliquely backward to the pectoral fin, the other at the posterior part of the yolk, and extending ventrally at its posterior border. One or two isolated groups also occasionally occur along the ventral border. All retain their periblastic position.

The vesicular condition of the yolk is not readily seen after hatching, though it can always be made out by careful manipulation of the light, or in favourable positions. The vesicles appear to be flattened out at the margin of the yolk. In some, peculiar vesicles are observed in the yolk-sac in the neighbourhood of the posterior oil-globules.

On the second day the yolk has considerably diminished, and its posterior border moving forward carries the oil-globules with it, leaving a larger space between it and the vent. Minute pigment-specks now appear in the eyes. The segments of the yolk are still indicated.

On the fourth day the yolk has still further shrunk. The cavity of the mouth is formed, though no external aperture yet exists, and the gut terminates blindly a little within the margin of the fin. The remarkable size of the optic lobes of the brain gives the larval sole a "hooded" aspect, and its agility is characteristic.

Three days later, that is on the 7th day, the activity of the larval fish is even more marked, and it seems in a state of perpetual movement, the only interval being for a second or two after a long course through the vessel. This almost ceaseless movement is probably connected with respiration, the now widely open mouth being driven against the water which rushes into it. Of course were the larval fish in currents sufficiently strong, its habit would be different, as it would simply keep its head against the stream, as in the young plaice and young turbot in the apparatus at Dunbar. The breast-fins (pectorals) vibrate like those of the sea-horse (*Hippocampus*), a resemblance the more appropriate from the dermal process on the head, and the tail appears to move as rapidly. Like other pleuronectids in still water the larval soles chiefly kept to the bottom of the vessel at this stage, swimming obliquely with the head directed downward, as if boring into the bottom or sides. Occasionally, however, a swift dart was made right across the vessel, or a shorter one as if capturing prey. The mandible (lower jaw) moves regularly as in respiration. The yolk has now diminished to a small mass anteriorly, with groups of oil-globules crowded together, while the posterior region of the abdomen is occupied by the viscera. This forward progress of the yolk is interesting, for while different conditions occur in the series, one of the most common is the absorption of the anterior region, and the consequent presence of the diminished yolk posteriorly. Another feature of note is the occurrence of a prominent fold along the ventral margin of the abdomen. The pigment seems in some to be more decidedly ochreous, and to have less of the dull yellowish-white (like Tripoli powder) so characteristic of the early condition. Along the dorsal margin of the muscle-plates are a series of pigment-patches, which appear to be more numerous than in the example of the post-larval stage, but variations may occur in this respect.

As the larval sole gets a little older, for instance two days subsequent to the preceding stage, the pigment becomes more distinctly ochreous, and the yellow chromatophores along the dorsal edge of the muscle-plates show signs of increase. Moreover, the pigment-spot on the occiput, so characteristic of the subsequent stage, is outlined. Eight distinct patches occur behind the former, one of the posterior (seventh from the occipital) being larger, and almost meeting that from the inferior edge. The character of the head is as peculiar as in the previous stage, so that the active little fish can readily see ahead. The yolk has now shrunk to a small mass under the liver, in front of the gall-bladder, and is not easily distinguished. The change from the buff or stone-coloured, or even the dull yellowish white, of the early stage, to the ochreous tint of the present one is a feature of interest. The latter begins in very minute points over the head and body, gradually spreads and supersedes the yellowish white, which disappears. The differentiation of the two is clearly seen at certain stages, the yellow being characteristic of the body, and the pale buff or dull whitish of the marginal fin. Moreover, the disappearance of the yellowish-white pigment from the edge of the marginal fin, so conspicuous in the early larva, and which renders it so easily observed in a glass vessel, is another alteration of moment. The speckled condition may be associated with the more helpless stage, when, perhaps, it frequently rests on the bottom, but this is conjectural. At any rate, the border of the marginal fin, at this and the post-larval stages, is so translucent as to be generally invisible, only the pigment-touches arising from the border of the muscle-plates being seen. The other parts of the head and body, as well as the under-surface of the abdomen, are speckled with ochreous and black pigments. The breast-fins have their fan-like blades directed forward, so that the larva seems to row itself onward by their rapid motion; the basal part of each is also invaded by the yellowish pigment. The great depth of the head and the prominent ridge over the optic lobes of the brain are characteristic. The eyes are silvery with black pupils, and as usual a dark arch occurs superiorly. The skin-fold along the median line of the abdomen next day was marked by a central gap, so that it formed two portions, and the anterior one a day or two later became broad and almost vesicular. Such changes, however, may have been partly due to confinement.

The next stage in the development of the sole was captured in the bottom-net by Cunningham[1] at Plymouth in May, 1890, and in this the early post-larval stage is reached. The notochord is bent up posteriorly, and the caudal fin-rays are beginning to appear. The eye is bluish, and the auditory vesicles are large. Definite pigment-spots occur on the dorsal and ventral fin-membrane—about six on the former and four on the latter, as indicated in Cunningham's figure, which

[1] *Jour. Marine Biol. Assoc.* May, 1891, p. 70.

seems to have been taken after death, or at least after the outline had been altered.

An older stage, again, 5 mm. in length, was procured two years previously in St Andrews Bay by aid of the mid-water net, viz. on the 22nd August, 1888[1], and a figure (Plate XVIII, fig. 3) by Mr J. Pentland Smith, M.A., B.Sc., from the native little fish, which lived in the Laboratory for some time, is here given. A careful comparison of this figure with that of Cunningham confirms the opinion formerly expressed. The body had considerably increased in depth, the notochord was bent up posteriorly, and the cartilaginous elements (hypural) were developing beneath, while the fin-rays of the tail were evident. The most conspicuous feature in coloration was the presence of deep ochre-pigment in the marginal fins, dorsally and ventrally, this having taken the place of the pale larval pigment formerly alluded to. The first spot occurred at the occiput, and was so conspicuous in life that when darting through the vessel it seemed as if furnished with a spur on its head. Behind were other finely branched pigment-areas, somewhat conical in shape, the base being at the margin of the muscle-plates of the body. Two less distinctly marked spots appeared in the ventral marginal fin, each being somewhat behind a vertical line from the corresponding dorsal area. A series of small stellate spots ran along the margin of the body, dorsally and ventrally, various chromatophores of the same hue extended over the abdominal surface and on the head and cheeks, and many minute blackish specks occurred on the same regions as well as on the sides. Along the margin of the body specks of similar pigment were present between the large and small chromatophores. The eyes were relatively small and of a bluish silvery aspect. A specimen at a similar stage of development is described and figured by Ehrenbaum[2].

An example 11 mm. long, and apparently of this species was procured by Mr Gamble on the 9th August; and Mr Cunningham[3] describes the presence of an air-bladder, which

[1] W. C. M. *Seventh Ann. Rept. Fishery Board*, 1889, p. 305, Pl. III, fig. 4.
[2] *Op. cit.* Taf. V, fig. 30.
[3] *Jour. M. B. Ass.* 1891–92, p. 327, Pl. XIV, fig. 2.

disappears when only a very little older. The coloration consisted of black and orange chromatophores, and more diffuse patches of lemon-yellow, but the pigment was not arranged in the manner characteristic of the adult.

The next stage is that described by Cunningham, viz. from $\frac{1}{2}$ to $\frac{5}{8}$ inch in length, and with the eyes on one side (right), that is after transformation and the disappearance of the colour from the left side. It was procured on May 15th, so that presumably it is the young of that year in the south (Mevagissey).

Young specimens of the sole occur in the estuary of the Thames in October and are caught in the shrimp-trawls. They average from $2\frac{3}{4}$ to $3\frac{1}{4}$ inch in length and evidently belong to the same season's brood. On Cunningham's estimate of the spawning-period as extending from March to May inclusive they may be from five to eight months old.

Cunningham, whose opportunities for the study of this species have been very favourable, states that specimens $2\frac{3}{8}$ to $2\frac{1}{2}$ in. were obtained by Holt from April to June, and these appeared to be 9 or 10 months old, probably however, amongst the smallest of the series. The sole reaches 6—7 inches the first year, 9—11 the second year, and from 9—15 during the third year.

It has been supposed that certain fishes, such as the sole and turbot, only spawn in deep water, where there is sufficient pressure to aid in the process. Those entertaining this notion have therefore pointed out the futility of attempting to keep soles for spawning purposes in enclosed shallow areas, as in connection with the Dunbar Hatchery of the Fishery Board for Scotland. As occasionally happens in such cases facts make the best critics, for within a brief period after the issue of this view the soles were spawning freely in the shallow tanks at Plymouth. It is true these and other flat fishes are somewhat difficult to treat during their spawning-period in confinement, but there is no reason to suppose that such obstacles cannot be overcome by care and perseverance.

So far as regards the larval period the sole is one of the hardiest of flat-fishes, and its subsequent stages exhibit no delicacy of constitution. If suitable arrangements were therefore made, the hatching and rearing of this species to the post-larval and subsequent stages may reasonably be anticipated. But, besides the artificial hatching of the eggs, further experiments like that performed by one of us in 1893 with the aid of the Fishery Board, should be made in transferring adolescent soles from English to Scotch waters. In the case mentioned no difficulty was experienced in transporting about 500 soles from Scarborough and the Humber to St Andrews Bay.

The Variegated Sole or Thickback.
(*Solea variegata*, Donov.)

A deep-water form seldom beyond $8\frac{1}{2}$ inches in length, and only occasionally met with in the west and north of Britain. The spawning occurs in April and May, and as in many species the females are somewhat larger and more numerous than the males. Mr Cunningham states the larva when first hatched resembles that of the sole, but the pigment is lighter. It is 2·42 mm. in length (not quite $\frac{1}{10}$ inch), and thus considerably smaller than the larval sole. "The youngest fully developed specimen was 1·8 in. long, taken in July, two miles south of the Eddystone. This specimen was possibly only three months old, but more probably a year."

Cunningham[1] obtained off the Eddystone an egg which he provisionally identified with that of this species. It measured 1·36 mm., and was characterised by numerous rather large oil-globules scattered singly at nearly equal distances over the surface of the yolk (Plate IV, fig. 12). It also had a superficial layer of yolk-segments. The egg thus approaches that of the little sole, but is considerably larger.

The Little Sole or Solenette. (*Solea lutea*, Risso.)

The small pelagic eggs of this species were first clearly recognised by Mr Holt when surveying, under Mr Green and Prof. Haddon, the fishing grounds of the west coast of Ireland

[1] *Journ. M. Biol. Assoc.* 1889—90, p. 23, f. 15. *Ibid.* 1891—92, p. 104.

in 1890. They were obtained abundantly at the surface of certain bays from the 15th June to the 8th July. He also found a nearly ripe female in Galway Bay on the 2nd June. The same year (1890) they were procured in St Andrews Bay; the earliest on the 4th May, and others in July, also at the surface. Canu describes the same form at Boulogne-sur-mer. Recently Ehrenbaum[1], who also found the eggs in June, gives good figures and examples of the larval, post-larval and metamorphosing stages. In the eastern forms the oil-globules, which are restricted to the vegetative hemisphere (Plate IV, fig. 11), are larger than in the Irish specimens and the cortical yolk-segments are small. The diameter is ·775 to ·835 mm., according to Holt, and some are ovoid. Since the above date they have been regularly procured in the tow-nets on the eastern shores in or near sandy bays, and their hardihood renders hatching easy.

A closely allied egg (Plate IV, fig. 13), though with smaller oil-globules, has occurred in St Andrews Bay during April and May in the trawl-like bottom tow-net; it is probably a variety of the former. Its diameter is ·762 mm. or slightly smaller than the foregoing. The largest oil-globule is ·004 mm. At first sight the capsule seems to be thick, but this appears to be due to the presence of a space (perivitelline), which throws into relief the wrinkles of the capsule and also the micropyle. The fine lines and creases of the capsule slightly resemble those in the lemon-dab, but they may have been due to immaturity or contraction of the egg; yet the two examples were precisely alike. The oil-globules greatly exceed in number those of the ordinary egg of the solenette—the figure showing all the oil-globules present, that is, both the deep-seated as well as those near the upper pole. Moreover in the centre inferiorly, and therefore at the germinal pole, was a pale protoplasmic mass or vesicle (?) considerably larger than any oil-globule, with a few granules and an oil-globule at its edge, this of course being of no particular moment as a special character. In the eggs of April and May, besides the much greater number of small

[1] *Op. cit.* p. 312, Taf. V, fig. 35 and Taf. VI, figs. 31—34, 1896.

oil-globules, the whole surface of the yolk is dotted with minute granules of oil, as indicated in the figure. Holt mentions that in his examples the oil-globules were restricted to the vegetative hemisphere, both in the early and advanced stages of the egg—a condition which differed from that in either of the eggs figured, so that probably a change subsequently occurs. In the egg of April, the yolk was invested by a conspicuous layer of protoplasm, which fixed the majority, if not the whole of the globules, and in a ruptured egg it could be observed to peel from the yolk, carrying the oil-globules in its folds. A similar belt of protoplasm is seen in the ordinary egg of the solenette in Plate IV, fig. 11; and as no trace of yolk-spheres occurred in the eggs of April and May, and only a few small ones in the last-mentioned figure, it may be that both are early stages, and perhaps those of April and May unfertilised. The rarity of the latter condition, however, in pelagic eggs is well known. It is also noteworthy that an egg resembling the ordinary egg of the solenette occurred at the surface, whereas the form alluded to here came from the bottom. Considerable latitude, however, must be given both in regard to distribution and to the size of the oil-globules.

Specimens of the 23rd June (captured in St Andrews Bay), in which the disc was beginning to spread out, had the main oil-globules at the vegetal pole, and only a few smaller at a lower level—one or two approaching the centre. On the 25th, the tail of the embryo was free from the yolk, which was marked by delicate reticulations, while pigment of a pale or dull whitish colour was developed over the head, body and yolk-sac. They were hatched about the 4th day afterwards, this period agreeing with what Holt found on the west coast of Ireland, or about 5 days in all. In the larval fish (Plate XVIII, fig. 1), which measures about 2·02 mm., the elongated form of the otocysts, the large oil-globules, which, with one or two smaller, form a row along the posterior curve of the globular yolk-sac, and the whitish-yellow pigment (somewhat like that of the common sole) are diagnostic. The breast-fins have a bar of the same pigment. The bend of the gut to the left (when viewed from the dorsum) is marked, and the reticulated condition of the yolk appears like fine meshes over the surface. By transmitted light the pigment is dark and finely dendritic. Holt gives 2·02 mm. as the total length of his examples, while those of one or two days were 2·14 mm., the yolk reduced, and the oil-globules fewer; indeed, at St Andrews, these appear to be in some cases fewer from the first. On the fourth day he found the length 2·38 mm., the increase being in the region behind the vent. The mouth is now marked by a deep pit. In a few days the oil-globules disappear, and patches of yellow pigment occur in some along the dorsal and ventral fins. The usual changes in the development and relations of the organs are carefully recorded by Holt. Chief amongst these are the deposition of black pigment in the eyes, and the great elongation of the region behind the vent. The post-larval condition (Plate XIX, fig. 13) is reached in eight or nine days, and then the yellowish pigment acquires a greenish hue, while the dorsal fin is expanded in the anterior region. The total length is now from 2·98 to 3·10 mm. They are restless and hardy, as in the case of the common sole. Holt also found them extremely hardy, so that with very little attention they were easily reared in small vessels to the post-larval condition.

The next stage is given by Ehrenbaum, and measures 6·3 mm. The body of the fish is considerably augmented in depth (Plate XIX, fig. 14), especially in the abdominal region, while the anterior end has become more truncated. Pigment has increased along the edges of the muscle-plates, and on the ventral surface of the abdomen. The breast-fins are also much larger. Only one or two indistinct touches of pigment of a greenish-yellow colour occur, and thus the contrast with the sole is pronounced. At the length of 7 to 8 mm. metamorphosis takes place, fin-rays and interspinous processes are present, and the left eye has appeared on the ridge. A notch superiorly in the caudal region indicates a trace of the larval tail. The pigment is still confined to the margins of the muscle-plates, the head and abdomen. At 8·2 mm. in August both eyes are on the right, and only a slight notch in front of the dorsal fin indicates the passage of the left eye. Pigment is now grouped in touches on the interspinous regions, and on the dorsal and anal fins.

In regard to the later stages an example 46 mm. in length was procured in the bottom-net in St Andrews Bay on the 5th July. This was in all probability at least a year old. Another $4\frac{1}{2}$ in. long occurred on the 16th January, and in this the reproductive organs were not developed to any extent. Fulton found ripe specimens at $3\frac{3}{4}$ in., and Cunningham considered this length would be reached at the end of two years.

CHAPTER X.

Physostomi.

Ventral fins abdominal in position; duct of the swim-bladder open; inferior pharyngeal bones distinct.

The Argentine Family. Sternoptychidæ.

The Argentine. (*Maurolicus Pennantii*, Walb.)

Day observes—"As the ova, which were large, were ready for shedding in examples captured in February and the milt was similarly forward, it appears that off Scotland they must breed during the earlier portion of the year." It is not stated whether the eggs were pelagic or demersal.

The Garfish Family. Scombresocidæ.

The Garfish or Garpike. (*Rhamphistoma belone*, L.)

Like the sparling this fish has eggs (fig. 40) with long adhesive filaments which attach themselves to various objects, and, as Day observes, on what grounds we do not know, "may bind together large numbers of eggs into one mass and fix such to some suitable substance." He also states that along the south coast of England the breeding-season is May and June, but in Ireland July. From the appearance of the ovaries of those captured in the middle of April the latter would seem to be near the spawning-period in Scotland. It appears to frequent estuaries, *e.g.* the Eden, for breeding.

At Naples Mr H. C. Williamson procured the eggs abundantly in May.

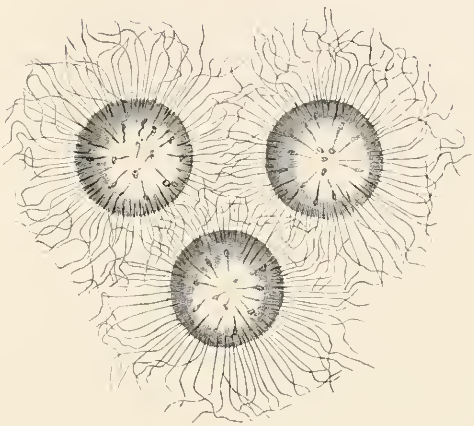


FIG. 40. Eggs of the Garfish. A. T. M.

In the *Scandinavian Fishes* it is stated that the garpike, approaching the coast, spawns in spring and the early part of summer, from April to June. The older fishes spawn first. Ekström observes, "This fish begins to spawn in the island-belt of Mörkö. The males and females then ascend together in large shoals to spots along the coast where the water is shallow. I have never seen the roe of this fish in the water; but it is probably deposited on the weeds, for it is always on a weedy bottom that the garpike is found during the spawning-season. The roe I have found, on cutting open specimens ready to spawn, was fine greenish-yellow in colour." "According to Benecke the eggs are from 3 to $3\frac{1}{2}$ mm. in diameter, the surface being covered with numerous hair-like filaments, some of them 1 cm. long, by means of which they anchor themselves. They develop so quickly, and the fry grow so fast, that as early as August we may find small garpike 150 mm. long (Malm), and during the summer Fries took a specimen 170 mm. long." After spawning they pass into the Baltic, but return in autumn in fine condition[1]. It is clear, however, from the condition of

[1] *Scand. Fishes*, pp. 351, 352.

the specimens subsequently to be alluded to, that considerable doubt arises as to whether the forms just mentioned are not older.

The young of this species as well as that of the saury-pike has a snout like an ordinary bony fish, as shown by Malm and Lütken. At 13 mm. both jaws are short, like those of the flying-fish, but such was not the case in an example 10 mm. long (in spirit) obtained by Mr H. C. Williamson at Naples in June, from a series artificially fertilized. The pigment at this stage is much more dense than at the subsequent one, and the head and eyes disproportionately large. The prow of the mandible projects rather more than the long (horizontal) diameter of the eye, and as in the subsequent stages, is deeply pigmented. True rays occur in the dorsal and anal fins, but the pectorals seem to have only coarse embryonic rays. No trace of ventral fins is present. The ventral surface is as deeply pigmented as the sides. In those at 15 mm. the lower jaw projects, with a protuberance, bent downwards, under the tip, while the upper jaw is still almost truncate. At 25 mm. the lower jaw stands out considerably, and along its middle inferiorly is a dermal fold, black at the margin, which much resembles the corresponding growth in the true *Hemiramphi*, for which the young were long mistaken. When 60 mm. long the mandible projects much, and the upper jaw (premaxillary region) also is prolonged some distance. The tip of the snout is marked off by a little sinus on each side. Teeth appear in the part of the lower jaw opposite the upper. At 70 mm. both jaws have elongated, the upper being about a quarter the length of the lower. Instead of having a slight hollow in front of the eyes, the snout is now more or less straight and sharp. When 150 mm. long the snout assumes the typical form of the garpike's, though the upper jaw is still shorter than the lower[1].

Other interesting features in the development of these forms are the persistence of the larval marginal fin, and the late appearance of the ventral fins. At 15 mm. the marginal fin is present at the lower caudal margin, between the anal and caudal. Again, from the vent to the end of the first third of

[1] Abstract from the *Scand. Fishes*, p. 346.

the abdomen, a great part of it, measuring more than half the depth of the body, is persistent. The tail-fin alone contains distinct rays. True rays now form in the anal, anterior part of the dorsal, and upper part of the pectorals. No trace of ventrals appears, though their site is indicated by blackish green pigment. When 25·5 mm. long these fins are visible as minute lobes. Williamson's second series of specimens from Naples ranged between 20 and 27 mm. on the 3rd September, and all had the larval marginal fin with embryonic rays stretching from a little behind the pectoral fins to the vent. The other fins had true rays. The least of them, viz. 20 mm., showed the ventral fin as an undifferentiated bud on each side. The lower jaw projected in this example nearly the length of the head, while the upper was shorter than in a sand-eel of the same length. The body throughout was speckled with dark brownish pigment (in spirit), but it only invaded the caudal fin. A silvery sheen appeared on the abdomen, the sides of the body and head. At 27 mm. the chromatophores had mostly disappeared from the ventral surface of the abdomen, and the sides were more silvery, a lateral band appearing in some along each. Williamson found a young copepod parasitic on the gills of these forms—clinging with its claws to the throat ventrally. At 53 mm. (*Scand. Fishes*) the abdominal marginal fin is still present, but the pigment-spots on the abdomen and sides inferiorly have to some extent given place to the silvery sheen. The ventral fins are only about half-a-millimetre long.

Skipper or Saury Pike. (*Scombresox saurus*, Walb.)

The eggs of this species are stated by Day to have external filaments as in the previous form, though it would appear, he says, that the young of the skipper wander further seawards. Lütken has figured the heads of various stages, showing that the disproportion in the length of the jaws is less than in the garfish.

The only young example procured in St Andrews Bay measured 13½ inches during October. It was probably in its second year.

The Herring Family. Clupeidæ.

The Anchovy. (*Engraulis encrasicholus*, L.)

Prof. Hoffmann found that the anchovies of the Zuyder Zee were ripe in the months of June and July and that the eggs were of an oval form, transparent, and about 1 mm. long. In July 1886, Wenckebach captured the same eggs in his tow-nets, and hatched them on the third day. The egg (Plate IV, fig. 21) is ovoid, and with the yolk reticulated as in other clupeoids, such as the sprat. Raffaele procured the same egg at Naples from May to September, and also ascertained that hatching took place after two or three days. He gives the long diameter of the egg as 1·15 to 1·25 mm. and the shorter 0·5 to 0·55 mm. He figures the larva on hatching (Plate XVIII, fig. 6) as provided with a reticulated yolk of little depth but of great length, extending indeed considerably beyond the middle of the body; while the notochord is unicolumnar. In two or three days after hatching, the yolk had greatly diminished (Plate XVIII, fig. 7), the pre-anal fin-membrane was augmented, and the dorsal had likewise passed much further forward. The mouth had also opened, and four branchial arches were visible. The yolk had completely disappeared about the 4th or 5th day, and pigment occurred in the eyes and along the dorsum of the body. The intestine was transversely ridged (Plate XVIII, fig. 8).

Day observes that they spawn off our coasts in September and December, though in June specimens have been found with enlarged roe, and so tender that they burst on the slightest interference.

Hoffmann thought that very rapid growth took place during the first year, so that those spawned in June and July reached a length of 12 cm. (= 4·6 in.) at the end of October. Dr Hoek appeared to agree with him. Ehrenbaum, however, asserts that the young anchovies referred to were in their second year, and this would be more in harmony with what is known of the herring, the pilchard and the sprat. He also considered that it breeds when two years old.

Until recently no pelagic eggs of the anchovy had been procured in Britain, though Mr Jackson of Southport found some with ripe ovaries in June, 1878[1]. One of us received from Mr R. L. Ascroft, of Lytham, certain eggs in the contents of a tow-net off Lytham pier on the 26th June of last year, which were identified as those of the anchovy at an advanced stage (Plate IV, fig. 22). Ascroft had hatched the larvæ and found seven lateral sense-organs on each side. They were straight and rigid and were active swimmers. The long diameter of these eggs after preservation in solution of formalin ranged from 1·295 to 1·447 mm., the shorter diameter being almost constant at ·685 mm. They were thus larger than those from the Mediterranean or the Zuyder Zee, but they were not measured in a living condition. The pelagic fauna amongst which these eggs occurred at Lytham was peculiarly rich in *Noctiluca*, arrow-worms, larval annelids (*Nerine* and *Polydora*), *Cypris*-stage of Cirripedes, Copepods, larval mollusks, *Appendicularia* and other forms, denoting both a considerable temperature and congenial surroundings[2].

By the kindness of Mr H. C. Williamson, we had the opportunity of examining specimens of newly deposited eggs and larvæ procured from the Bay of Naples on the 17th August, so that the spawning-period in our country agrees with, though it may not begin so early or continue so late (September), as that at Naples. The larger Neapolitan eggs had a long diameter of 1·295, and most had a shorter diameter of ·685 mm., as in the British examples. The remarkable elongation of the yolk, its vesicular condition and the structure of the notochord are diagnostic in the larval anchovy.

The distribution of the fish in British waters has been described by Prof. Ewart, Dr Fulton and Mr Cunningham.

The Herring. (*Clupea harengus*, L.)

The herring occupies in several respects a unique position amongst the important food-fishes. In the first place it stands out conspicuously as the only one which deposits its eggs upon the sea-bottom or, in other words, has a demersal

[1] *Fide* J. T. Cunningham, *J. M. B. Assoc.* 1889–90, p. 332.

[2] W. C. M. *Nature*, Vol. 54, p. 296, July, 1896.

egg. We may recall the fact that all gadoids and pleuronectids, whose development is known, have buoyant pelagic eggs, and amongst the nearer relations of the herring we find that the sprat, pilchard and anchovy have the same character of eggs and spawning-habit. A reference to the table of eggs will show that, by this mode of classification, the herring is juxtaposed amongst a number of the humbler and weaker little shore-loving fishes, such as the blennies, gobies, gunnel, suckers and sticklebacks, which all breed near the shore in the locality which they frequent throughout life. These fishes with demersal eggs are, apart from other considerations, too small as a rule to be of much importance as food-fishes, though all contribute to the nourishment of the latter. The cat-fish, wrasse and lumpsucker form exceptions to this generalisation in point of size, but on the other hand they cannot be regarded as food-fishes to any important degree.

Perhaps the eggs of the herring and its clupeoid allies when compared with those of the gadoids give one of the most instructive examples of the endless variety and resource of Nature. In the case of the four common clupeoid species, the herring, sprat, pilchard and anchovy, the most superficial examination of their eggs with the naked eye is sufficient to distinguish between them. The opacity, and thick adhesive membrane of the first, the translucence and delicate capsule of the second, the clear perivitelline space and oil-globule of the third, and the unique shape (ovoid) of the last are all characters readily recognisable without the assistance of the lens. On the other hand, in the case of the gadoids, the eggs resemble each other so closely in structure that the difference in size alone serves to distinguish them, and in many cases even this feature is not diagnostic. If we attempt to explain the resemblance of the eggs of the cod, haddock, green cod, poor-cod, whiting and bib as the result of genetic affinity, to what shall we ascribe the marvellous divergence in structure and appearance of the eggs of the herring, sprat, pilchard and anchovy?

The herring, therefore, in having a demersal egg, is quite the exception amongst British marine food-fishes. It may be recollected that in the early days of the agitation against trawlers, which still continues to the present day, the great objection urged against the indiscriminate use of the trawl was the reckless destruction of fish-spawn involved. With increase of our knowledge it came to be recognised that the spawn of the herring alone of all the food-fishes could lend itself to injury, the eggs of the other fishes being, by virtue of their physical character, safely removed beyond the reach of the trawl. On the other hand, if an injury to the spawn of the herring,—sufficiently great to cause a diminution in the 'catch' of herrings,—could be proved scientifically to be inflicted by the trawler in pursuit of his avocation, then, the herring alone is so extremely important to the community at large as a source of food-supply, that prohibitive legislation might well be imposed. It is not within the scope of this work to enter into this difficult question, but it is well to call to mind that the eggs of the herring are as a rule deposited in very definite restricted areas and that they are minute, adhere firmly to foreign bodies and have a tough elastic capsule. In the Report to the Trawling Commission (1884) it was remarked, "The trawlers either do not seem to work on the ground selected by the herring for spawning, probably because the latter would prove too rough, or the passage of the trawl over such is unattended with the presence of ova in it...... Even if a trawl did pass over masses of herring-ova, it is questionable if injury would always occur." Again, there are millions of herrings caught every year, which are either ripe males or females, and with the death of one of the latter is involved a loss to the species of many thousands of potential individuals. Under these circumstances, it is not surprising that the indictment against trawling now tends to emphasise the destruction of young fishes, of the food of the fishes and the actual fishing-gear of the liners. So far as at present known, the herring appears to be able successfully to defy the combined exterminating energy of man and of its natural enemies in the sea.

From another point of view the herring is exceptional, in that it is the historic species upon which the earliest observations on Teleostean development were made. This has been partly caused, or at any rate made possible, by the fact that, by the nature of the case, large masses of its spawn are accessible to investigators, and partly, perhaps even more than this, because the case of the herring is one of the few instances in which public authority, in the form of Governments, has shown sufficient belief and interest in scientific effort to offer assistance (pecuniary or otherwise) for the elucidation of the many problems connected with its life-history. The direct benefit to be derived from a thorough knowledge of the spawning-habits and grounds of this species was so obvious that it appealed, with some measure of success, to the Administrative intelligence. Thus we find, from the beginning of this century onwards, that the Governments of Britain (through the Scottish Fishery Board), of Norway, Sweden, Denmark and the United States, have at one time or another bespoken scientific men to unravel the problems connected with the spawning and migrations of the herring. We may well review very briefly some of the most important literature of this subject which more directly concerns us.

In 1803, Dr Walker, then Professor of Natural History in Edinburgh University, described the reproductive habits of the species under consideration. He stated that the herring deposited its eggs on a selected gravelly bottom at about 10 to 12 fathoms; its fry reached a length of one to two inches in June, and about three to four in September, when they "desert the places where they breed."

In 1860 Dr Boeck, acting under the Norwegian Government, investigated the spawning of the herring. He found that gravelly basins were chosen for deposition of the eggs[1], and he also concluded that herrings are shore-loving fishes, never going far out from the coast. Their movements are influenced by wind and temperature.

This was, in part, corroborated by Lord Playfair and Prof. Allman, acting in the Royal Commission of 1862, who found that the spawn, collected in 14½ to 20 fathoms near the Isle of May, adhered tenaciously to anything upon which it happened to fall, be it stones, gravel, shingle, coarse sand or even the

[1] In the Museum of one of us is an example of the truth of this, viz. a quantity of gravel mixed with the eggs of the herring, which distended the stomach of a cod.

shells of living crabs! The adults were plentiful on the spawning-ground from the 6th of March to the 13th, and disappeared on the 25th. When spawning the herrings lie in tiers, covering square miles of sea-bottom and so close to the ground that the fishermen have to practise a peculiar mode of fishing in order to take them. The shoal rapidly disappears after spawning. They found the period of incubation to be from 25 to 30 days, and that there are two spawning-periods, one in the spring, February and March, and another in the autumn, August and September. Similar observations have been recorded by later workers.

In 1874, under the German Fish-Commission, there appeared a series of investigations on the herring. Dr A. H. Meyer made some valuable observations upon the eggs and young. He found that at a temperature of 53° F. the eggs hatched in about 8 days, whilst at 38° F. the period of incubation was prolonged to 40 days. He concluded that the disappearance of herrings from their usual spawning-banks has perhaps sometimes resulted from a lowering of the bottom-temperature. He also showed that the length of the fry when hatched varied with the time required for development; fry measuring $\frac{1}{5}$ in. (5·8 mm.) when development was rapid, but $\frac{1}{3}$ in. and having a smaller yolk-sac when prolonged. Some embryos, hatched in 14 days, were kept in Kiel Bay and were found to have lost their yolk in 3 days. Other observations of Dr Meyer and their bearing are mentioned in the chapter on Rate of Growth. Dr C. Kupffer gave a detailed description of the developmental changes during the embryonic and larval periods, and from his account we shall quote largely.

Dr Heincke attempted to show that the autumn-herring is anatomically distinguishable from the winter one, whilst Ljungman, acting under the Swedish Government, besides corroborating several of the observations of his predecessors, found that herrings avoided light and their movements were therefore largely determined by the diurnal cycle. He also ascertained that during the prevalence of sea-winds the shoals shun the shore, approaching the land however when the winds blow offshore.

In 1878 certain investigators under the United States Fish-

Commission succeeded in artificially fertilizing and hatching the spawn of the herring.

In 1881 Hoffmann published an account of the development of the herring founded on observations on eggs from the Zuyder Zee. Kupffer's description has been largely corroborated by Brook and other British workers, and a few notes upon the later stages have been recorded by Holt and others at St Andrews Marine Laboratory.

This very brief *résumé* of the literature upon the development of the herring is not by any means exhaustive, but will serve to indicate the fact that contributions to our knowledge have been made by a great number of observers of different nationalities. It is scarcely needful to state that the accounts do not all agree, but the points of difference are less connected with the observed facts than with the inferences drawn therefrom.

The sexes are about equal in number, though if anything the males are slightly in excess. A single female will carry on an average about 30,000 eggs, though as many as 47,000 have been recorded. This is not an excessive fecundity and is much below that of pelagic-spawning fishes. The time of spawning both of the spring- and autumn-herring shows considerable variation at different parts of the coast. For example, the autumn spawning-period on the east coast of Scotland is August and September, and off Yorkshire it is in October. As far south as Suffolk and Kent it is as late as November.

The egg of the herring (Plate IV, fig. 24) is from ·92 to 1 mm. in diameter, some are as small as ·85 mm. Boeck, however, found that the Norwegian herring had an egg of at least 1·5 mm. diameter. The membrane surrounding the egg is tough and elastic and is multilaminar; a radial striation can be observed, as in many other species. Most authorities agree that the membrane consists of two layers (Kupffer, Boeck, Hoffmann), and the last-mentioned gives the thickness of the outer layer as ·01 mm., that of the inner ·0225 mm. Both are perforated by fine canals, those of the inner layer being the finer. The two layers may be easily separated by special methods. Hoffmann interprets them as integral parts of the one egg-membrane (*zona radiata*), and gives reasons for supposing that this *zona* is a true vitelline membrane, which could thus be compared with the vitelline membrane which occurs in other fishes. Kupffer, on the other hand, maintained that the herring was exceptional (though two membranes have been described for the egg of the pike) in that the two layers must be interpreted as two egg-membranes, the inner being the commonly occurring vitelline membrane. On the whole it would seem to be likely that the capsule of the egg of the herring corresponds to that in other forms, but with a tendency to greater differentiation of the laminæ.

The membrane is covered, immediately upon extrusion by the female, by a layer of viscid material which causes the eggs to adhere together or to any foreign body with which they may come in contact. The viscid substance rapidly hardens on exposure to the water and then presents a fibrous structure. This occurrence of an adhesive material is not exceptional amongst demersal eggs. The yolk is opaque, and is close to the membrane, leaving a very small perivitelline space. Kupffer found that the egg-elements could be distinguished under three heads. Firstly, shining homogeneous globules which were strongly refractive and varied in diameter from ·008 to ·02 mm. These were massed together under the membrane and formed the superficial layer of the yolk; he termed them yolk-granules. Secondly, the large central mass of yolk, consisting of less refractive bodies varying in size from ·05 mm. to ·08 mm.: these he termed the yolk-globules. Lastly, distributed sparsely between these yolk-elements is a scanty viscous mass of protoplasm. According to this observer, the homogeneous structure of yolk and yolk-protoplasm remains the same till fertilization, and no blastodisc or collection of the protoplasm at one pole is formed till spermatozoa have penetrated the egg-membrane. Hoffmann, on the other hand, finds the herring no exception to most other fishes in this respect also, and maintains that the blastodisc is formed before fertilization.

When this event (fertilization) has taken place the egg shrinks away from its membrane, so that a space filled with fluid is formed inside the capsule. At the same time, the formative yolk, or protoplasm, separates from the nutritive yolk as a continuous superficial layer surrounding the latter. Later it collects as a mass at one pole and forms the blastodisc. Segmentation of the blastodisc then proceeds in the usual way.

Development is rapid and by one and a-half days the embryo reaches three-quarters round the yolk. On the fourth day it shows signs of movement. On the fifth, the hind gut opens to the exterior, and there is little change from the 6th to the 7th days, on the latter of which the embryo hatches (Kupffer).

The length of the newly hatched larval herring is given by Kupffer as 5·2—5·3 mm., whilst Hoffmann found that his larvæ were 6·2—6.4 mm., and Boeck again records newly hatched larvæ of 10 mm. It should be borne in mind that Boeck found the North Sea herring's egg to be considerably larger than those of the Baltic and other parts. Newly hatched larval herrings occur every year in St Andrews Bay in early March, and they are usually about 7 mm. in length. The difference in size between the larvæ of Kupffer and Hoffmann may be accounted for by the variable duration of incubation: seven days in Kupffer's case, twelve days in that of Hoffmann. This has been clearly shown by Meyer, as indicated above, for he was able to vary the period of incubation by a change of temperature, within the limits of 8 to 40 days, and by this means obtained larvæ varying between the limits of 5·4 mm. and 9 mm. In the nature of the case, there is no inherent reason why the period of hatching should be fixed and definite, all the processes of development being uninterrupted by, and independent of, its occurrence. (See chapter VI, on Rate of Growth.)

The point of transition from the larval to the post-larval stage is a more clearly defined epoch in the career of the young fish, involving as it does many important physiological and morphological changes. It is at this time that the young fish really commences its independent existence, for the supply of ready-prepared nutriment or yolk then comes to an end and thereafter it has to depend upon its own exertions for obtaining the requisite food. By a reference to the general account of the development of these fishes it will be clear that the yolk-nutriment is made available for the recuperation of the tissues through the medium of the blood-supply, whereas the organisms which form the post-larval food require to be caught, ingested, digested and absorbed, and the indigestible residue got rid of, so that the organs of the alimentary canal, jaws, œsophagus, stomach, liver and intestine come into full play at this stage. In fact, in the embryonic and larval stages the fish is self-contained as regards its food-supply; on the assumption of the post-larval condition this state of affairs is altered and it becomes directly dependent in this respect upon its external environment.

This is true in the case of the transition from embryo to larva only as far as the sensory and locomotory organs are concerned. The accomplishment of hatching allows a more direct interaction between the muscular and sensory systems and their environment, but the larva is, as stated above, still completely independent of the latter in respect of alimentation. These considerations will serve to emphasise the point that the period of 'incubation' as measured by the lapse of time from fertilization to hatching is neither theoretically nor practically of specifically fixed duration. In the chapter on Rate of Growth this subject is further dealt with.

The newly hatched herring (Plate XIX, fig. 2) has been described and figured by several observers. As is seen in the figure, it is an attenuated form and the whole body is colourless and transparent. In several features this larva is more advanced than that of the sprat, thus *e.g.* the mouth already gapes widely, and the eyes are deeply pigmented. From an examination of freshly caught larval herrings in this Laboratory (St Andrews) undertaken to decide this point, there can be no doubt that the eyes of the larval herring are deeply pigmented and have, in life, a bluish-green metallic lustre. Holt has previously stated them to be of a brilliant silvery blue, whilst Kupffer affirms that they are black. Black pigment is present and can be seen at the outer edge of the iris and in the pupil; and the eyes of preserved specimens have a uniformly black colour. There can be little doubt that Cunningham's statement that the eyes are colourless and devoid of pigment is incorrect. In his recent book upon *Marketable Marine Fishes*, he agrees with Kupffer's statement.

The alimentary canal does not terminate immediately behind the yolk-sac but runs ventrally to the notochord for a long way, the vent being situated at a point about $\frac{1}{6}$ of the total length of the larva from the tail-end. This character appears to be common to all the clupeoids yet observed. Other clupeoid features are the unicolumnar notochord, the ovoid condition of the yolk-sac and the vesicular yolk. No ventral fins are yet present. The median embryonic fin is of course continuous and extends for a short distance upon the posterior border of the yolk-sac. In some instances pigment is found in the newly hatched herring and appears after a day or so in others. Black pigment is alone present, and 'consists of one or two median chromatophores below the heart, a chain of about ten commencing behind each pectoral fin and running backwards on each side of the gut for about half its length; an irregular, sometimes double, chain ventral to the posterior half of the gut; two (sometimes one) stellate chromatophores on each side, a little in front of and above the vent. Stellate chromatophores are also developed above the posterior end of the notochord, and more abundantly below it' (Holt).

Growth and development are rapid, and the yolk-sac is usually absorbed in about three or four days. Whilst this is being accomplished, the larva gains considerably in strength and activity, though still keeping near the bottom (Plate XIX, fig. 3). They are to be caught in great numbers in the bottom tow-net. The demersal habit therefore extends to the very early larval stage as well as to the embryonic. It will be remembered that the larval sprat and pilchard float helplessly in the surface- or mid-water, and are thus pelagic, as are the eggs of these two species.

The post-larval herring, however, freed from the encumbering yolk-sac, and probably led by its search for food, leaves the bottom and migrates into the mid-water. As a rule, these active little post-larval herrings may be caught in St Andrews Bay at the end of March, in the mid-water tow-nets, at about 4 fathoms.

The length of 10 mm. is reached at this stage. The eyes are prominent, with the same bluish sheen and black border which have been already noticed, the mandible projects forwards, the ear-capsules are large and swollen, giving the back of the head a bulbous appearance, the pectoral fins project outwards and the median fin is absent from the front part of the body. The specimen figured was nearly 9 mm. in length, and had not yet developed its black pigment to any extent. Considerable variations in this respect are to be observed. In comparing the young herring at this stage with the preceding, we are struck with the great elongation of the body and the conspicuous notochord. This organ, in fact, appears to constitute the greater part of the bulk of the body, the muscles and alimentary canal ensheathing it as a thin layer. The total length of the body may be as much as $23\frac{1}{2}$ times the greatest breadth.

The neighbourhood of the sea-bottom is now forsaken and the post-larval herrings seek the higher regions, moving up through the mid-water, in which they may be caught throughout April by means of the tow-nets. By the middle of the month they reach an average length about $\frac{1}{2}$ inch or more (12—15 mm.) and present the appearance indicated in Plate XIX, fig. 4. The body has 'filled out,' and the breadth and depth of the little fish bear a much greater proportion to the length than was the case heretofore.

The continuous embryonic fin has disappeared, leaving a permanent dorsal fin, some way back towards the tail. There is still, nevertheless, a trace of the median fin on the ventral surface, between the tail and the vent, in the position at which the permanent anal fin will arise later, and along the abdominal surface. The gills with their supporting arches and the jaws have undergone important changes tending towards the adult condition. The characteristic pigmentation already described is now very marked, with the addition of a few black spots dusted over the tail-fin. Little change takes place till the end of April, when an average length of about 16 mm. is reached.

By about the end of June the average-sized young herrings have reached a length of about 25 mm. (or one inch) and after a short sojourn near the surface commence their migration towards the shore, where at a length of 26 to 28 mm. these little herrings may be found in great numbers. The general appearance of the young fish may be seen in Plate XIX, fig. 5. The chief differences from the last stage are the alteration in shape of the body owing to greater increase in breadth and the increase of black pigment. The former causes the young fish to resemble the adult more closely in its proportionate dimensions. The position of the vent is further forward and the anal fin has appeared. The ventral fins arise as a pair of folds about half way between the vent and the gill-slits. The black chromatophores in the wall of the abdominal cavity have increased and further continue to do so, although the growing opacity of the body-wall gradually hides them from view. The row of black dots below the intestine may now be seen, not only under the posterior half of this organ but anteriorly as well. Finer black pigment-spots cover the general surface of the body, especially dorsally, and on the tail. The tip of the notochord is bent up dorsally at its caudal end, and the eyes are very large and conspicuous.

Shortly after this the silvery sheen of the adult commences to appear, especially on the head and lateral line, and the young herring reaches the 'whitebait' stage. Although at one time the 'whitebait' (*Clupea alba*) was claimed by some naturalists as being specifically distinct from the other clupeoids, there can now be no doubt that it is the young stage, in the majority of cases, of the herring and in a few cases of the sprat. The proportion belonging to each of these species in any given 'haul' depends largely upon the locality and the season.

Pennant, as early as 1776, examined the whitebait of the Thames and declared them to be neither young shad, sprats nor smelts, but was inclined to consider them to be the fry of the bleak. Donovan later examined some whitebait and considered them to be the young of the shad, and later still Yarrell contradicted the results of both his predecessors. He claimed for whitebait a separate species and named it *Clupea alba*, the whitebait representing mature individuals. Cuvier states that the whitebait (*C. alba*) frequent brackish water to mature their spawn. This was carried still further by Valenciennes, who actually attempted to found a fresh genus (*Rogenia*) for these little fishes. Subsequent investigators have not been able to confirm the results of these last naturalists, nor indeed those of their predecessors, for it now appears to be an established fact, as already stated, that 'whitebait' are the fry of the herring, with which may occur a certain proportion of young sprats. Examples of 'winter whitebait' examined by Day included some sprats as large as 4½ inches long, with 'well-developed roe,' whilst some of the young herring were as long as 7½ inches.

Numerous whitebait from the Thames and elsewhere have been subjected to minute examination by well-known naturalists and no individuals presented structural features which could not be reconciled with the view that they are the fry of the herring and sprat[1].

Before following the young herring beyond this stage we may glance at the later brood.

In the accompanying diagram (p. 418) a graphic system of representing the life-history of the herring has been adopted. This system, though to a large extent self-explanatory, has been referred to in the chapter on Rate of Growth, and also in 'The Lesser Sand-eel.' In it the course of the young spring-herring can be traced as narrated above, but we may also note the occurrence of another 'crop' of larval herrings in August and September. The earliest of these may be traced through the same journey as the spring larvæ, namely from bottom to mid-water and thence to surface, eventually migrating to the littoral region, but amongst the later larvæ the migration becomes less marked (see diagram), and the very latest appear never to leave the bottom, but to migrate shorewards at once, without an intermediate journey through the mid-water and surface. It may be that this is an adaptation to the exigency of a rapidly approaching winter, and the less abundant supply of pelagic food in the later part of the year. In the autumn-series the littoral habit is assumed at an earlier stage, at least as regards length, than in the spring-series. These interesting differences may all be reasonably explained as the direct result of the different environment in each case.

The autumn-larvæ differ from their spring-relatives in

[1] Vide the observations of Prof. Ewart and the late Mr James Duncan Matthews. *4th Report Scot. Fish. Board*, p. 98.

another respect:—their average size upon hatching is appreciably less, a result which could have been prognosticated, when the higher mean temperature in August compared with that in

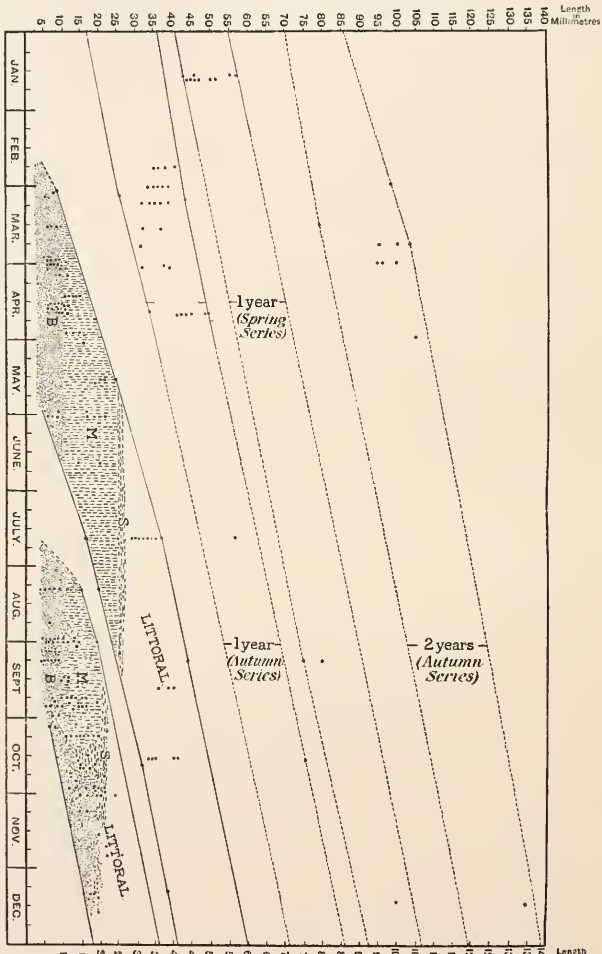


Fig. 41. Diagram representing the life-history of the herring. B = bottom (dots); M = mid-water (perpendicular lines); S = surface (horizontal lines).

April is considered. (See *Rate of Growth.*) The autumn-brood, like the spring, eventually reach the shallower water and are found in great numbers (whitebait) in the estuaries of rivers. These whitebait, when kept in confinement, swim in swarms round and round the tanks by day, but at night they separate, dart about rapidly in search of food and appear to feed principally after dark.

The young herrings appear to haunt the shore throughout their first winter but on the approach of spring move away to the open water, at least they are not caught in any numbers near shore throughout the second summer.

We may briefly summarise the life-history of the young herring as follows, always remembering that the cycle is only followed out in detail by the typical individual, and that a margin must be allowed for variations such as have been seen to occur in the later autumn-brood.

The young larva, hatched at from 5 to 7 mm. in length, lives near the bottom till about 10 mm. is attained by a rapid increase in length. The attenuated post-larval herring then migrates upwards through the mid-water to the surface, the mid-water stage lasting from about 10 mm, to 23—24 mm., and the surface-stage from 24 mm. to 27—28 mm., when a movement shorewards takes place, and the littoral habit is acquired.

In dealing with the sand-eel, we summarised as follows :

'The post-larval sand-eel remains at the bottom till a length of about 10 mm. is reached. Living alongside of it are found great numbers of larval and post-larval herrings, usually somewhat larger, and young *Sagittæ*. There is a remarkable superficial resemblance, caused solely by the attenuated form of these three very diverse organisms, which is, of course, entirely absent in the adult stages.

'At a length of somewhat over 10 mm. the young sand-eel commences its migration upwards through the mid-water, and at this period its growth is very rapid. The average date for this change of habit will be seen to be about the end of April. By the third week in May, or sometimes earlier, the surface will be reached, and in the three weeks' migration through the mid-water the little fish will have grown from 10–11 mm. to 17–18 mm., a very rapid rate of growth. The surface-period lasts from 17 mm. to about 30 mm., and extends from the third week in May till the second week in June or thereabouts, when the adult habitat is adopted. Here, again, in about three weeks, the young sand-eel grows from 17–18 mm. to about 30 mm. Sand-eels of larger sizes are caught at the surface, as almost everywhere, the universal distribution of this species being well known.'

An inspection of the diagram given here will show that this description will apply in almost every detail to the spring-herring. The sand-eel has a slightly greater average length (30 mm.), on leaving the surface-water, than is the case with the herring, but at this late stage the adult characters are being assumed, and the herring, although shorter, is more robust. The similitude between these two species is completed by the demersal spawning-habit and the occurrence of two spawning-periods during the year, the earlier of which is the more important. These facts serve to emphasise the importance of investigations amongst the humbler species of fish which are not themselves used, to any important extent, for human consumption, a study of their life-history affording valuable clues to further knowledge of the more important food-fishes.

The estimation of the growth of the young herrings is complicated by the double spawning-period, with a space of less than two months intervening. It is probable, however (see diagram), that a maximum length of about 70 mm. (nearly 3 inches) is reached by the expiration of 12 months, and this is increased to 125 mm. (5 inches) by the end of the second year. Spawning probably takes place at the latter end of the third year, when a length of 8 to 9 inches may be reached.

The mean curve in the diagram for the spring-herring would give a growth-rate as follows:—

1 Month . .	15 mm.	8 Months . .	47 mm.
2 ,, . . .	20 mm.	9 ,, . .	50 mm.
3 ,, . . .	27 mm.	10 ,, . .	54 mm.
4 ,, . . .	30 mm.	11 ,, . .	58 mm.
5 ,, . . .	35 mm.	12 ,, . .	62 mm.
6 ,, . . .	40 mm.	18 ,, . .	87 mm.
7 ,, . . .	44 mm.	20 ,, . .	98 mm.

The rate of growth, according to this table, agrees closely with a mean increase of 4–5 mm. per month.

The mean growth of the autumn-herring works out as follows:—

1 Month	14 mm.	8 Months	43 mm.
2 ,,	19 mm.	9 ,,	47·5 mm.
3 ,,	23 mm.	10 ,,	52 mm.
4 ,,	27 mm.	11 ,,	57 mm.
5 ,,	30 mm.	12 ,,	61 mm.
6 ,,	34 mm.	18 ,,	88 mm.
7 ,,	38 mm.	24 ,,	113 mm.

The early stages, in the winter-months, give a comparatively slow rate of growth (3–4 mm.), but the length of the one-year-old autumn-herring is approximately equivalent to that of the spring-fish.

The largest specimen in the St Andrews collection is one of 134 mm., which, according to the table, would be about 27½ months old and belong to the autumn-brood.

As regards the migrations of the herring, the same theories as in the case of the mackerel (see Mackerel) have been held. Some have supposed that shoals of herrings migrated from the Polar seas southward every year, and others have suggested that myriads of herrings take an annual excursion round the coast of the British Isles. It is probable that the migrations are greatly localised, and that apart from an annual migration inshore connected with the function of spawning there are lesser migrations of the shoals in quest of food. A pelagic fish of gregarious habits like the herring must of necessity be more or less itinerant, in order to satisfy the demands of hunger. This species appears to live mainly upon minute crustaceans and larval sand-eels, etc. which make up what is known as the pelagic fauna, and the movements of these, mainly controlled by changes of temperature and weather, probably determine the lesser migrations of the shoals of herrings. During the breeding season the function of alimentation is largely in abeyance, which enables the 'shoaling' to take place to a greater extent than would otherwise be possible.

There is considerable difference of opinion with regard to the varieties of herring which frequent the coast of Scotland. Dr Heincke came to the conclusion that the Baltic herrings were of two varieties, and that each of these varieties could be subdivided into a summer- and an autumn-variety according to their spawning-period. The spring-herring of the Baltic appear to spawn in brackish, shallow water, and in the Schlei they spawn in water that is practically fresh. They thus form a transition-type, through the shads, to the regular freshwater demersal-spawning fishes.

Duncan Matthews, after an exhaustive examination of a great number of Scotch herrings, was led to believe that the summer- and winter-herrings could be distinguished by small structural features, such as the 'more posterior position of the dorsal, pelvic and anal fins, the doubtfully smaller head and the slightly lesser size' of the former, but he considered that the differences were not sufficiently defined to warrant the term 'variety' being applied. If it were a difference of size alone the larger mesh of the nets used in the winter would probably account for the fact. All questions with regard to the later rate of growth and the prevailing abundance of herrings of different sizes are complicated by the fact that herring-nets catch practically only one size of herring. (See *Rate of Growth.*) Valenciennes gives 13½ inches as the maximum length attained by the North Sea herring.

So far as one can pronounce with any certainty upon a very difficult point, we may say that the herring attains sexual maturity at a length of 8—9 inches, and this is probably during the third year.

From the diagram it will be seen that the sizes 3 inches and 5 inches may be taken to represent a rough average of the size of a herring when one year and two years of age respectively.

The Pilchard. (*Clupea pilchardus*, Walb.)

This member of the well-defined clupeoid group of food-fishes is intermediate in size between the herring and the sprat, and is otherwise distinguished from both by a number of markings on the gill-cover, by the large scales and the position of the dorsal fin.

The development of the pilchard has not been followed at St Andrews, for it is many a year since pilchards were found in any abundance off the east coast of Scotland; in obedience to some natural laws, of which we know nothing, this fish has disappeared from our shores. Parnell, writing in 1838, remarks that 'the pilchard has become a very rare fish in the Firth of Forth as well as along the whole eastern line of Scottish shores.' Few appear to have occurred since 1816.

Under these circumstances we must seek the annals of the southern naturalists for data with regard to its development, and in doing so we encounter considerable diversity of opinion, even with regard to the facts. Couch, writing in 1865, says that, 'In April and May they are habitually prepared to shed their spawn, which they now do at a further distance from land and even 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.' Mr M. Dunn, a practical fisherman of the south-west coast and a careful observer, gives a spawning-period of May and June and again in December.

These two observers agreed in regarding the pilchard as having two spawning-seasons in the year, as is also the case with its close ally the herring (see Herring). Day, as narrated in his work upon British Fishes, states that he opened and examined a great number of pilchards in August and in only a single instance did he find ripening ova—an observation which tends towards the view that Couch in stating the second spawning-season to be in October placed it rather too soon, and it also appears to militate very strongly against the opinion, held by some, that the pilchard spawns continuously from April to December. Cornish has put forward reasons for supposing that this fish spawns during the mackerel-season, namely, from February to June.

Prof. Marion at Marseilles finds that the sexual organs ripen in October and are ripe from December till March, even on till May, whilst Cunningham at Plymouth found pilchards' eggs in the tow-nets on August 11th and again on November 9th, and obtained others from the ripe females on September 5th. It remains for future investigators to harmonise these conflicting opinions and statements, or at any rate, to discover the truth with regard to this much-vexed question. No doubt the special environment in each case will tend to cause a disagreement in results, when compared by calendar months, for the date of spawning is probably determined in the main by the mean temperature at the particular period.

The ripe female carries about 60,000 eggs, a small number compared with other pelagic food-fishes. Most authorities appear to agree that the pilchard spawns far from land, probably from 20 to 50 miles offshore and that the egg is of the pelagic type.

In this connection Couch makes a remarkable statement: '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 the 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.' Whilst attaching due value to Couch's remarks, as those of a competent naturalist, we cannot but think that there has been a mistake; the whole subject of the spawning of marine fishes was so obscure till recently that such an error is the more excusable. As Cunningham has pointed out, Couch's description tallies most with the general appearance of the spawn of the Angler-fish, though it is probable that other appearances than the latter misled him.

To Dunn must be ascribed the first observation, in 1871, of the pelagic spawn of the pilchard. A spawning pilchard was captured and came under his cognisance at Mevagissey Bay, and he noted, not only that the eggs were pelagic and floated freely, but that they were translucent, like others of the same type.

Raffaele, working at Naples, found a particular pelagic egg in the tow-nets which he considered to be that of the pilchard. This egg presents many striking features (Plate IV, fig. 23). It has a large perivitelline space between the egg itself and its outer membrane, a characteristic which is found in such an entirely different species as the long-rough dab, but it may be at once distinguished from the latter by the presence of an oil-globule which is in the usual position, within the yolk-sac. Raffaele gives the diameter, over all, as 1·5 to 1·7 mm., that of the egg proper as ·8 to ·9 mm., and that of the oil-globule as ·16 mm. The yolk is covered with large reticulate markings, due to the mass being composed of radial sections which are compressed tightly together, leaving polygonal surface-markings. This feature is well developed in the sprat's egg, and an allied form of yolk-structure is found in that of the herring.

The herring, the sprat and the pilchard are about as closely allied species as are to be found, yet the eggs of the three could not possibly be mistaken, for in the first case we find a small opaque demersal egg occurring in masses, in the other two a translucent floating egg, both with polygonal yolk-markings, but the latter having a large perivitelline space and an oil-globule. This great diversity in the structure of the egg is found to extend still further in the case of the egg of the anchovy, which Raffaele describes from Naples and one of us from Lytham, and which is almost unique amongst pelagic types in being of an elongated form. It is not uncommon to find a departure from the geometrical accuracy of a sphere in some species, but the anchovy's egg may be almost described as cylindrical in outline. (See Anchovy.)

Raffaele succeeded in hatching the eggs above referred to, and found that the period of incubation lasted from four to five days. The temperature of the tank-water during this time varied from 9° C. to 12° C. He also gives a view of the egg with its contained embryo at a fairly advanced stage of development.

Cunningham has since found eggs corresponding to Raffaele's description in the tow-nets at Plymouth, and agrees with the latter in regarding them as those of the pilchard. There is little to note concerning the development within the egg, which conforms closely to the clupeoid type. Cunningham found an interesting example of a pilchard's egg which had a very much reduced perivitelline space, in fact no larger than in the normal sprat's egg. The embryo within hatched successfully and appeared perfectly normal, although developing under such abnormal conditions. Variations such as this may possibly be explained as atavistic, and would in this case point to the conclusion that a large perivitelline space has been secondarily acquired from an earlier type of egg with a small space of this nature.

Plate XIX, fig. 1, gives the appearance presented by the larva upon hatching; the very sparse supply of pigment, the sub-terminal position of the vent, and the unicolumnar notochord are all clupeoid characters. The yolk-sac is large, with the oil-globule still persisting at its hind region; the vesicular nature of the yolk is marked. Cunningham gives the length of the newly hatched larva as 3·8 mm., and he also mentions an entire absence of pigment, which however does not appear to be general, for Raffaele describes and figures sparsely distributed black spots on the head and trunk, and later the former observer has found 'a few black chromatophores along the dorsal region of the body.' In an entire absence of pigment in the eyes immediately after hatching the pilchard agrees with the sprat, but contrary to a statement by Cunningham, disagrees with the herring, which upon emerging from its demersal egg has deeply pigmented eyes (Kupffer, Brook, etc.).

These larvæ referred to were hatched by Cunningham at Plymouth Laboratory in September. The temperature of the tanks being about 17° C., the period of incubation was shortened to three days. They agree with those quoted above from Raffaele's observations. When hatched there is no external opening of the mouth, the head being depressed upon the yolk-sac. About the third day after hatching the mouth is open and owing to the elongation of the lower jaw it soon assumes a terminal position. At this date the eyes which hitherto had been colourless presented a little yellow pigment and 'reflecting substance.' On the day after this, viz., the

4th day, the body has elongated and the supply of yolk is rapidly diminishing, the eyes are now black and opaque, whilst the black chromatophores have encroached upon the ventro-lateral region: by the end of this day there is hardly a trace of yolk. At the age of five days the larvæ have reached a length of 5·5 mm., and the yolk has entirely disappeared, bringing to a close the true larval period. By ten days the whole brood had expired, the conditions in captivity seemingly being unfavourable to further development. We may notice in the nine days' post-larval form the elongated body (cf. Herring and Sprat), the long alimentary canal ending in a sub-terminal vent, and the unicolumnar notochord. The continuous embryonic fin is still present, being only interrupted by the vent. There appears to be a very conspicuous post-anal gut, running from the vent to the extreme posterior end of the notochord. A few fin-rays are seen in the caudal region. The entire absence of all pigment in the fins is noteworthy, as is also the presence of only black pigment upon the trunk and head.

From this brief account it may be said that we know the leading features of the embryonic and larval development of the pilchard, but we know nothing of the habitat in natural conditions during this epoch.

It is reasonable to suppose that the larva remains in the surface and mid-water whilst the process of yolk-absorption is proceeding, partly because of its helpless condition and partly from the analogy of other forms, but we must wait for further light upon the fate of the post-larval forms. Do they move downwards as they approach the shore and pass their young stages at or near the bottom, as in the case of so many other species, or do they remain at or near the surface? These and other questions must be left unanswered at present.

In the work already referred to, Prof. Marion gives an account of the sardine fishery and the names by which the young pilchards are known at various stages in their growth. He states that the young sardines remain for the whole of the first year in the Gulf of Marseilles, and they grow at the approximate average rate of 1 centimetre (= $\frac{2}{5}$ in.) per month. At a length of 2 to 4 centimetres they are known as 'poutines nudo,' so called because at that young stage they have not the silvery coat acquired later. At from 4 to 5 cms. they are known as 'poutines vestido,' having now the silvery sheen of the adult. Later they are known as 'palailla' and 'sardinettes.'

The sardines average about 6 to 7½ inches (16 to 18 cms.). As regards the rate of growth, the poutines of 1·2 to 1·6 inch (3 to 4 cms.) occurring in March, grow to a length of 4·7 to 5·1 inch (12 to 13 cms.) by December. If we assume these to be spawned in February then by one year they are from 14 to 15 cms. long (nearly 6 inches). At the end of two years they reach a length of 18 cms. (about 7¼ inches), and presumably they spawn in the third year. Cunningham, from examination of pilchards in August during the regular fishing, concludes that some pilchards spawn in their second season when they are about 8 inches long. He found young pilchards in the estuaries of the south coast 2¾ to 4⅝ inches in length in September and surmises that they were spawned in May or June, giving them a maximum age of 5 months. The pilchards of the Channel and Atlantic Ocean appear to be a considerably larger race than the sardines of the Mediterranean although they are probably identical species. Thus Prof. Pouchet at Concarneau finds that the largest are from 9½ to 10 inches, whilst Cunningham records them at 9½ inches. Cornish found an example 11⅞ inches in length, and Dunn yet again reports one of 14 inches, a size which compares well with that of the herring.

Pilchards are, as is well known, essentially gregarious fishes, and although their shoaling and migrations are no doubt primarily connected with the sexual function yet the lesser movements appear to be largely determined by the distribution of food and by currents. Day states that off the coast of Cornwall and Devon they are said to remain all the year, moving near the bottom in January, and in the summer migrating seawards some 20 to 50 miles offshore, probably in connection with spawning. Off the Channel Islands the schools of pilchards are familiar to zoologists in July and August—as they break the surface-water over considerable areas like a deluge of great raindrops.

THE SPRAT. (*Clupea sprattus*, L.)

One of the most remarkable features about the sprat is the fact that, in spite of its very close relationship to the herring, it has an egg and larva of the pelagic type in direct contrast to the demersal spawn of its congener. The mature female appears to carry about 5000 to 5400 eggs, more or less, a very moderate amount in comparison with most fishes of the same spawning-habit.

Great numbers of eggs of this species occur in the bottom tow-nets, indicating that they often take up their position at or near the bottom. Confining the remark to the Forth we may seek a partial explanation for this in the fact that the buoyancy of pelagic eggs is dependent on the specific gravity of the egg being less than that of the medium, and also that the sprat appears, so far as we can be guided by the distribution of captured eggs, to spawn well up the reaches of the estuaries; in such a position the water must incline towards brackish. The medium therefore, in such cases, being of less specific gravity, and that of the egg constant, the result is that the egg fails to rise in the water. The same result would occur in the case of any pelagic egg, if the spawners assumed a brackish habitat, as is exemplified in a remarkable manner by the eggs of the shad as described in 1889 by Prof. Pouchet. They closely resemble those of the pilchard though devoid of an oil-globule, but as they are laid in fresh water they sink and lie separate and free on or near the bed of the river. The intermediate character of these eggs, between the pelagic and demersal types, is very interesting; pelagic in structure but demersal in habitat, they give an insight into, at any rate, one way in which a pelagic spawning-habit may be changed to a demersal one. These facts all tend to show how slight a distinction really exists between pelagic and demersal ova.

In the Frith of Forth the eggs of the sprat are found further inland than any others, and are more plentiful there than elsewhere. Thus about the district of Inchkeith eggs of the sprat are abundant, and they are comparatively rare in the outer stations beyond the Isle of May, where the eggs of the haddock and cod abound.

The sprat appears to commence spawning about the end of April and, in the areas indicated, its eggs are the commonest form throughout May and June and into July. In the south they spawn earlier, indeed Mr Cunningham[1] speaks of procuring them in January at Plymouth.

The egg is readily distinguished by a very thin capsule, a beautiful translucency and a fine network of markings over the whole surface of the yolk. It is usually about ·04 inch in diameter, Plate IV, fig. 19, though some, not round, have the shorter diameter ·039 in. (·94 to 1·2 mm.). The embryo, even up to hatching, is perfectly colourless. The sprat is an essentially oily fish but there is no trace of an oil-globule in the egg, showing that there is no necessary connection between these two features.

The period of incubation is short, and the larva when hatched, Plate XVIII, fig. 4, has no trace of pigment and measures 3·07 mm. to 3·6 mm. There are peculiar paired lateral sense-organs, and the vent is situated posteriorly, a marked feature of the larval herring and sprat, and probably a clupeoid characteristic. The marginal fin is slight and the larva is not so elongated as that of the herring. The notochord is unicolumnar.

After 9 or 10 days of larval existence (Plate XVIII, fig. 5) the supply of yolk has considerably diminished and the snout protrudes in front of it. The mouth is not yet open but the breast-fins are well-developed. The eye is slightly silvery but otherwise there is no pigmentation. The sub-terminal position of the vent is still diagnostic. At this stage the little larvæ in the Marine Laboratory died. They are pelagic and very delicate.

Ehrenbaum found that in a week the yolk was absorbed, and the early post-larval conditions assumed at the length of 4·7 mm. (Plate XIX, fig. 7). Black pigment was well-developed in the eyes, while two rows occurred along the alimentary canal,

[1] *Journ. Mar. Biol. Assoc.* I, (N. S.) p. 45.

viz., dorsal and ventral in the posterior region, dorsal only in the anterior region. Black chromatophores also extended along the ventral edge of the muscle-plates behind the vent. The otocysts were large and the pectoral fins formed rounded flaps.

On the 18th of July the same author describes a translucent post-larval sprat of 18·5 mm. (Plate XIX, fig. 8) in which the pigment had increased in the eyes, along the gut, and in the tail-fin (schwangflosse). The body is more elongate and proportionally deeper.

The sprat becomes silvery when between 25 and 33 mm. long, and scales then develop.

Young sprats with adult characters occur in August and September. Day mentions that the 'frith' of the Devon and Cornwall coast and estuaries consists of 'young sprats': he found them from $\frac{3}{4}$ to $2\frac{1}{2}$ inches long at Dawlish and about $1\frac{3}{4}$ inches at Teignmouth. 'During the summer and autumn months young and small sprats are rarely absent from our coasts.'

The exact habits of the sprat are not known, the above author remarking:—'Although during the very cold months herrings and pilchards more or less retire to the deep, sprats on the contrary come towards the shore; but even when present the shoals are capricious in their movements, as well as in their extent....Even the time of appearance varies considerably in different years at the same place.' On the east coast of Scotland the sprats appear to occur shortly after the herrings, but are not much sought after for food, although abundant in the estuaries of the Forth and Tay. Enormous quantities, however, are frequently sold for manure, a waste of valuable fish-food which is a criticism upon the legislative measures in other departments.

The connection between young sprats and 'whitebait' has been mentioned under the 'Herring.'

Thus we notice that much has yet to be known concerning the migrations and life-history of the sprat. As already indicated, it appears likely that the adults resort to the estuaries for spawning, but it is known that they cannot face quite fresh water. Cunningham remarks that they migrate seawards to spawn, on the south coast, and the eggs are frequent in St Andrews Bay.

In regard to the rate of growth Cunningham observes that in February, March, April and May little sprats of 2 or 3 inches are about a year old. When 4 to 4½ inches Mr J. Duncan Matthews found them ripe, and this probably in their second year.

The Allis Shad. (*Clupea alosa* (pt.), L.)

This form probably spawns at the same period as its ally, the twaite-shad, viz. from May to July. It ascends rivers for this purpose, and the roe (ovaries) of an example of about 8 lbs., captured in the Tay on the 28th April, 1862, filled the abdomen to a large extent, yet the eggs were small, and apparently by no means at maturity. They were not in layers or folds as in the salmon, but connected by intermediate tissue.

The ripe egg resembles that of the other members of the family in having a reticulated yolk, and like the pilchard a large perivitelline space, which, as in the long-rough dab, is developed after its issue from the ovary, and greatly increases the size of the egg—to nearly 4 mm. in diameter, while the yolk is little more than a third of the bulk. The eggs roll in a separate condition on the bottom.

A complete description of the eggs and larval form of this and the following species would be very desirable. Cunningham in an interesting criticism of the views of Ehrenbaum and of Metzger and Hoek is of opinion that the young examples of the allis shad taken in April, May and June and ranging from 9 to 13·6 cm. (= 3·5 to 5·3 in.), are the young of the previous year; while those captured in October and November, and having the length of 7·2 to 14·3 cm. (= 2·3 to 5·4 in.), are those hatched in the preceding spring.

The eggs of the American shad (*Alosa sapidissima*), like the foregoing, are slightly heavier than the water, so that they remain in suspension near the bottom.

The Twaite-Shad. (*Clupea finta*, Cuv.)

The eggs of this ally of the herring are deposited in fresh water, the fishes entering rivers for this purpose; thus the adults are occasionally procured in the Tay and other British rivers in spring. Ehrenbaum observed that the eggs when shed (at night in the end of May) were 1·5 to 1·6 mm. in diameter, but as in the other species, the perivitelline space gradually enlarged till the diameter reached 4·2 to 4·6 mm. They hatched, at a temperature of 66°, on the fourth day. The reticulated yolk and other features corresponded with the previous species.

The newly-hatched larva is about $\frac{1}{7}$ of an inch long, with only traces of pigment. When 8 to 9 mm. long the yolk was almost absorbed, and the mouth functional. At 15 mm. the body was elongated and slender, with large otocysts, traces of permanent rays in the fins and tail, and with the black pigment best developed along the ventral edge of the muscle-plates. At the end of June those of 16 to 20 mm. had forked tails, a clupeoid outline, but no scales. On 6th July they were from 24 to 29 mm. in length and slightly silvery. They reached 36 to 46 mm. in the middle of July with scaled and silvery sides, the dorsal fin in front of the pelvics, and with well-developed pigment[1]. Ehrenbaum found the eggs of the twaite-shad in the Elbe in May with advanced embryos. Towards the end of the month he captured larvæ from 8 to 9 mm. Yarrell and Day give June and July as the spawning-period in our rivers, the latter having opened several in the Severn on June 3rd and found the eggs almost ready for deposition. Yarrell obtained the young $2\frac{1}{2}$ inches long in October, and 4 inches the following spring.

Ehrenbaum, again, captured young twaite-shads from 1·68 in. to 4·96 in. from August to the middle of November, and concluded that these were the young of the previous

[1] Abstract from Mr Cunningham's remarks, *Market. Fishes.* pp. 180 and 181.

year which had migrated to the sea as soon as the yolk had been absorbed, and had returned of the size indicated. Cunningham[1], from whose interesting criticism of Ehrenbaum, Metzger and Hoek's remarks this note is taken, says, 'What is to prevent the shad spawned in May from completing its metamorphosis by the middle of August and reaching a length of 1·68 to 7·8 cm. (= 3 in.)?' The herring, according to Meyer, is 8·4 cm. (3·3 in.) long[2] and upwards by the middle of November, 'and yet Ehrenbaum maintains that specimens of the twaite-shad, a larger fish when full grown, which are 8·0 to 12·4 cm. (= 3 to 5 in.) in November, are eighteen months old.' In the table of Metzger and Hoek the young twaite-shad captured between April and the 22nd June ranged from 7·2 cm. (2·8 to 4·2 in.) to 12 cm. (4·75 in.), and Cunningham thinks those are the young of the previous year, while those obtained between Oct. 4th and November 24th, and ranging from 5·4 cm. (2·125 in.) to 12 cm. (4·75 in.), are from the spawning of the same season, viz. the preceding spring. Those over 12 cm. captured during the latter months (Oct. and Nov.) "may very possibly be in their second year."

The Eel-Family. Murænidæ.

The Eel. (*Anguilla vulgaris*, Turt.)

When the persistent efforts of generations of observers have eventually been rewarded, as no doubt they will, by a solution of the problem of the life-history of the eel and when the facts are then made known, a complete history of the various conjectures and hypotheses which have been hazarded, taken in comparison with the correct data, will afford one of the most fascinating chapters in the whole record of natural history. Even at this stage in our knowledge many pages might be filled with a mere enumeration of the superstitions by which

[1] *J. M. B. Assoc.* 1891—92, p. 261.

[2] Compare with rate of growth of herring in British Waters, pp. 420—422.

ignorance has attempted to cloak itself, in connection with the reproduction of the eel.

In some parts of Britain even educated persons will assert in good faith that the young eel owes its existence to the spontaneous vitalising of stray horse-hairs, and Jacoby mentions that Sardinian fishermen cling to the belief that a certain beetle (*Dytiscus Roeselii*) is the progenitor of the eel, and they therefore call this beetle "mother of eels," and the same origin has been actually upheld in writing by Cairncross, who gives an account of the birth of two or three hair-eels from one of these insects, resulting in the death of the parent. Two of the offspring he claims to have kept for two years till they were 8½ inches long. He admits having lost sight of them for nine months!

The eel, like other animals, is often infested with thread-worms, and this has given rise to another assertion that it is viviparous; this statement is even mentioned and corrected by Aristotle. He remarks: 'Eels are not produced from sexual intercourse nor are they oviparous, nor have they ever been detected with semen or ova, nor when dissected do they appear to possess either seminal or uterine viscera...... It is plain, therefore, that they are not produced either from sexual intercourse or from ova. Some persons have thought that they were productive, because some eels have parasitical worms and they thought that these became eels. This, however, is not the case, but they originate in what are called the entrails of the earth, which are found spontaneously in mud and moist earth. They have been observed making their escape from them and others have been found in them when cut up and dissected. These originate both in the sea and in rivers where putrid matter is abundant; in those places in the sea which are full of uci, and near the banks of rivers and ponds, for in these places the heat causes much putridity. This is the mode of generation of eels.' It is hardly clear what the 'entrails of the earth' means; how near to the truth Aristotle may have been will be seen later.

Leeuwenhoek, as late as 1692, describes the urinary bladder of the eel as a uterus, and parasitic worms therein as the young.

When we state that Jupiter, various fishes, slime, old skins of water-snakes, and of eels, have all been saddled with parental responsibility to the young eel we may well draw a curtain over this superstitious speculation and turn to the known facts.

These have been recently collected together and summarised in an interesting paper by Mr H. C. Williamson, M.A., B.Sc. of this laboratory, and from his account we largely quote below.

In the beginning of April, 1885, a young eel $3\frac{1}{4}$ in. long was found in the sand near low water-mark at St Andrews differing from those which ascend the lade by the greater translucency, and another has since been found in the same region. The blood was only faintly pinkish[1]. So far as known this is the earliest condition of the eel—before migrating into the adjoining rivers and streams.

The next stages of the eel, called 'elvers' in England, 'civelles' or 'montée' in France, form a delicate article of food in both countries and are caught in great numbers in the rivers and streams in spring and early summer. They are transparent little eels of some 6 to 7 centimetres in length (2·5 inch). In the elver, while there is yet no trace of sexual organs, there are present all the essential characters of the adult eel, viz. the swim-bladder, the projecting lower jaw, and the dorsal fin commencing much nearer the middle of the body than the pectorals. There is no pigment in the skin. In the elvers examined at St Andrews the vertebral column, from the presence in it of a large quantity of black pigment, shows itself distinctly through the transparent body-wall as a dark line. The eyes are large and very black. The nasal tubes are proportionally larger than in the adult. The dorsal fin in the elver commences a very little further forward than in larger eels.

The sexual organs only become visible at the superior part of the abdominal cavity when the animal reaches the length of 20 cm. or thereby (7 inches).

According to Robin, the civelles in the sea as in fresh water lose their transparency when they arrive at the length of 6, 7,

[1] Vide W. C. M. 3rd *Ann. Rept. F. B. for Scotland*, Appendix, p. 63.

or 8 cm. 'At this period they take on the yellowish brown tinge of the adult. From the length of 9 cm. and better, 10 or 11 cm., they retain the preceding colour. They are then opaque, being with difficulty examined by transmitted light, and have, except for their length, the external appearance of the adult. These peculiarities are still more marked in individuals of the length of 12, 13, or 14 cm. According to Valenciennes it is at this period (April or May), three or four months after hatching, that they receive the name civelle. At this period, according to this author, they may be of a beautiful sulphur yellow colour.' Small eels $2\frac{5}{8}$ in. long occur between tide-marks in Lochmaddy, North Uist, even so late as August.

'The development of the eel from the civelle to the adult is regular—without metamorphosis, without the replacement of fœtal organs, which disappear, by others which replace them permanently.'

We thus notice that at the earliest age when the eel is known to us, both the larval and post-larval stages have been reached and passed, and it is only the young eel which comes under our cognisance through its migratory instinct.

The time at which the montée (schools of elvers) is said to appear, varies very much in different countries, and even in different parts of the same country. Robin says that, in the Landes, and no doubt other places in the south, the ascent of the young fishes takes place as early as the second half of December, instead of in March as in the Channel.

'Observations made on the Orne show that the sea exercises a sensible influence on the arrival of the little eel. The fishing is especially fruitful during the two days which precede, and the three days which follow, either the new or full moon. The fry, unable to stem the current, take advantage of the spring-tides to enter the rivers.'

The young eels on entering a river swim eagerly up stream. Numbers leave the main body and follow the course of each tributary. They overcome obstacles in a remarkable manner, ascending even perpendicular rocks by creeping through the *algæ* or wet moss covering the stones. They burrow readily into the soft mud. The ascent of the young eels has been described by many authors. Parnell, in this connection, says, 'In June the young are seen, from 2—3 inches in length, making their way up the fresh-water rivers in innumerable multitudes, keeping a few inches below the surface, and at a short distance from the bank. No obstacle appears to arrest their progress. They have been known to climb up posts, and to ascend into trees. They have also been observed crawling over land from one pond to another.' That eels very often travel over wet grass from one piece of water to another is a well-known fact. The presence of eels in ponds, into which they have not been introduced, and which are isolated from all other waters, can only be accounted for by the passage of the eels over land from a stream connected with the sea. Some persons have asserted that eels crawl over fields in search of slugs, etc. 'The adult eel,' says Jourdain, 'will travel over wet grass to ponds or water-courses which have no direct communication with the sea. Out of water, the eel swallows air into its branchial chamber, the straight opercular opening of which closes very exactly. The gill is then in a humid chamber, where the air gives up a portion of its oxygen to the branchial lamellæ, which can be partly separated from one another by the play of the muscles of the respiratory apparatus. This is one of the conditions which favour the long survival of the fish out of the water.'

The question as to whether or not the male eel enters fresh water has given rise to much difference of opinion. It was generally believed that the male eel never left the brackish or salt water near the coast, except at the period of reproduction, when it joined the females which had migrated from the fresh water streams. This view has now been modified. The observations of Hermes, Pauly and Feddersen have proved that males do go up the rivers into fresh water.

Such then are the general characters of the immigrations of the young eels into fresh water.

As regards the sexual organs we have already noticed that the female organ or ovary (roe) only commences to make its appearance after a length of seven inches is attained. The ovary of the eel was first described by Mondini in 1777, and independently, three years later, by O. F. Müller. In 1850 the first mature eel which had come under observation was examined by Rathke. The ovaries of the eel consist of two frill-like bands extending the whole length of the abdominal cavity, from the liver to beyond the vent. Each ovary is attached by its dorsal or adherent edge to the peritoneal covering of the swim-bladder and the upper part of the abdominal wall; its ventral border is free. The colour of the ovary varies according to the stage of development of the eel. In young eels 28·7 cm. (11·5 inches) long, it is glassy in appearance, with a very slight whitish tinge; in larger eels the ovaries, crowded as they are with eggs and fat spaces, are opaque and white in colour. The main interest attaching to the female sexual organs of the eel is the absence of any definite genital ducts, the ova no doubt being discharged freely into the body-cavity and from thence to the exterior by genital pores. This character is believed by some authorities to be primitive. As regards sexual diversity in size the eel appears to be no exception to most bony fishes in that the males are considerably smaller than the females. No male eel longer than 20 inches has been recorded, whilst females are frequently more than 3 feet in length.

Much attention has been given to the attempts to find external sexual differences in eels. Difference of colour, when taken together with certain anatomical differences, was considered to be of value in the separation of the sexes. The male was very often, invariably by Jacoby, found to have a metallic sheen on the sides of the body. The females were as a rule of lighter coloration on the back than the males. 'The snout of the female is not only much broader, with more prominent eyes, but is also more *depressed*, a characteristic to which I would call special attention, and one which I do not find in the male. In contrast, the snout of the male eel is more *convex* By paying attention to the two most important characters, viz. the relative proportions of the dorsal fin and snout, and, by their help, picking out those specimens which appeared to be males, I actually found 80—90 per cent. of those individuals so selected to be males with the Syrskian organ.'

Sennebogen observed that when eels are left dry, the female specimens give off far greater quantities of slime than the males, and that if the severed skin be examined through a microscope, the scales of the females are far smaller than those of the males.

Petersen has found that very distinct anatomical differences existed between the yellow and silver varieties of eels. 'The sides of the yellow eel are of a canary yellow colour, the back dark grey or brownish black. The belly is sometimes yellow, oftener white, the colours on the whole varying. Sometimes they have a slight metallic sheen, but as a rule this is absent. In fresh water the yellow colour is not so often met with as in salt. If the yellow eel be lean, the head appears abnormally large, and the eel has a strange and repugnant appearance. Both males and females are found among yellow eels.

The silver eels are distinguished by a very striking metallic sheen on the sides and belly. A bronze appearance is often seen in the neighbourhood of the lateral line in females as well as in males. The belly is usually pure silvery white. The eyes of the silver eel are much larger than those of the yellow eels of the same length, and rise up sideways so far that the lips, which are very narrow, are for the most part not to be seen outside the eyes if the head be looked at from above. The silver eel, according to the fishermen, are always somewhat sharp-headed, are fat and in much favour; the thick-headed specimens, which are only found among yellow eels, are in poor condition. The sexual organs of the silver eel are more developed, and heavier than those of the yellow eels of the same size.

He found yellow eels of all sizes from 6 cm. upwards, but he discovered no silver eels smaller than about 29—33 cm. in males, and 42—44 cm. in females. He is led to the belief that the silver eel is the yellow eel in its 'breeding dress' (Parungskleid). This explains why there are no silver females whose total length is less than 42—44 cm., and no silver males whose total length is less than 29—33 cm., for with those two lengths the two sexes become capable of reproduction. The change from the yellow to the silver coloration takes place rapidly—in a few weeks, and at the same time the breast-fins become black, while in some the anterior margin of the gill-slit is of the same colour.

Jacoby, whilst examining female eels, found certain individuals whose reproductive organs were very undeveloped, and which showed distinct outward differences from the ordinary female. These he regards as sterile females. The following description is taken from his article on the 'Eel Question':—'In Comacchio, and doubtless wherever large masses of eels live even in brackish waters, near the sea coast, a certain variety of eel exists, which I found were barren females of the common species. They are female eels whose ovaries show an entirely anomalous condition. On opening such an eel, one finds, instead of the well-known yellowish white and very fatty frill-like organ, a frothy thin band without any fat and having few folds, often as transparent as glass, otherwise of the same length and breadth as the frill organ, varying of course according to the size of the eel. If this band be examined under the microscope, the eggs appear transparent, containing but very few grains of yolk, or none at all. The band therefore appears an anomalously developed ovarium. The outward distinguishing marks of the barren females, which I found of all lengths up to 70 cm. (28 inches), are very striking. They show all the above-mentioned distinguishing marks of the female intensified. Their snout is broader, often—especially the point of the lower jaw—extraordinarily broad, the dorsal fin generally higher, the eyes decidedly smaller, in larger specimens astonishingly small, and the colour is generally a light yellowish-green; further the back is of a lighter colour, and the belly of a brighter yellow than in the common female eels. In Comacchio, this eel is called 'pascuite[1].' By the term 'pascuite,' however, the fishermen understand immature normally developed eels, as well as the sterile females. The sterile females grow as large as ordinary females, but never leave the brackish waters.' According to Comisa, the barren female may probably, under certain conditions, develop into a normal female.

What little we know concerning the eggs themselves has been gathered from an examination of ripe or nearly ripe

[1] The 'pascuite' appears to be identical with the yellow eel of Petersen.

ovaries. These have been found to contain great numbers of very minute eggs. In the ripe eel examined by Rathke the largest eggs only measured ·1 mm. in diameter. This is one of the two ripe eels which have been recorded, and it is remarkable that the eggs in this case were much smaller than those subsequently found in unripe ovaries. The largest eggs described by observers have been ·27 mm. in diameter. Syrski noticed that a more advanced state of development of the egg was found in those eels in which the *fissura recto-vesicalis* and the genital aperture were open, than in those in which they were closed.

As regards the male organ there has been some little doubt and uncertainty. What is undoubtedly the testis of the eel was first described by Syrski in 1874, under the name of 'lobe-organ.' No observer has, so far, found ripe spermatozoa in the lobe-organ of Syrski, but the histological examination of the lobes, made by several zoologists, have shown that this organ exhibits a minute structure, similar to that found in the immature testis of other fishes. The discovery of spermatozoa, also, in the homologous organ of the conger, by Dr Hermes, affords conclusive proof of the testicular nature of the lobe-organ. The testis occupies in the body of the male a position corresponding exactly to that of the ovary in the female.

Such then are the organs of generation in the eel; it will be seen that there is no feature in them in comparison with those of other fishes to lead us to suppose that there are any exceptional anomalies in the deposition of spawn and its connected phenomena.

Grassi[1], to whose work we refer again below, has been enabled to obtain from the straits of Messina male eels with ripe spermatozoa. He found that all the eels so obtained were 'silver,' and confirmed the suggestion of Petersen that the silver colour was a 'breeding dress.' He further showed that the pectoral fins become at this stage an intense black, and in some the anterior margin of the gill-cleft is of the same hue, whilst there is a marked increase in the size of the eyes.

Prior to maturation of the sexual products the great

[1] *Q. J. Mic. Sc.* Nov. 1896.

majority of the adult eels leave the streams and rivers and migrate to the sea. Some of the eels, however, remain in fresh water during the winter. That this migration to the sea is for the purpose of spawning seems to be proved by the fact that about the end of spring and beginning of summer, immense numbers of young eels enter the fresh water streams from the sea. While most authorities are agreed that the eels spawn only in salt water, some are of the opinion that they also spawn in fresh water. Roosevelt maintained that eels were hatched in fresh water in his trout-ponds in Great South Bay, Long Island. Sawyer also considered that eels do not all return to salt water to spawn, but spawn wherever they find suitable places in ponds and rivers. In this connection Benecke says that 'eels planted in land-locked ponds increase in size, but never increase in numbers. In lakes which formerly contained eels, but which by the erection of impassable weirs, have been cut off from the sea, the supply has diminished, and after a time only scattered individuals, old and of great size, are taken in them. If an instance of the reproduction of the eel in fresh water could be found, occurrences such as these would be inexplicable.' At the meeting of the Scottish Microscopical Society on the 16th of February, 1894, Mr George Sandeman called attention to some remarkable eels from a warm and stagnant loch on the Isle of May, which has no communication with the sea. He remarked that it was not known how long ago the eels were placed in the loch, but it did not appear to have been within the memory of man. They are not known to breed, their ovaries and testes being somewhat atrophied, though still apparently functional. In the specimens examined (at St Andrews Laboratory), atrophy is also marked in the muscles, liver and spleen. The ovaries and ova are very small, fatty, and the nuclei of the ova obscured. In appearance these eels are singularly bony. The specimens were all about 26 inches long, but weighed only one-half the normal weight. Perhaps the most interesting feature about them was their eyes, which in some examples were eight times larger than normal. The cornea is opaque, and attacked with gregarines and other organisms. These very remarkable abnormalities

Mr Sandeman believes to be due to senility. Dr Günther also, in the article on 'Ichthyology' in the *Encyclopædia Britannica*, writes,—'So much only is known that they do not spawn in fresh water, that many full-grown individuals, but not all, descend the rivers during the winter months, and that some of them at least must spawn in brackish water, or in deep water in the sea; for in the course of summer, young individuals from 3–5 inches long ascend the rivers in incredible numbers, overcoming all obstacles, ascending vertical walls and floodgates, entering every larger and swollen tributary, and making their way over *terra firma* to waters shut off from all communication with rivers.'

The eels leave the rivers and enter the sea in autumn, but according to Benecke, the migration begins in the upper stretches of long rivers in April and May, and in the lower reaches and shorter streams later in the season. Feddersen says that the migration of the male eel to the sea happens most usually earlier in the year than that of the female. The time of migration in any locality seems to vary a little, and to be dependent on the state of the river. The eel-fishermen on the Eden notice that the migration takes place on that river in the first heavy spate in October or November. The main body of the eels comes down during the first night; by the third night they have all passed down to the sea.

A comparison between the reproductive organs of the migrating eel, and those of the eel at other seasons of the year, would naturally be expected to afford conclusive proof that the migration is for the purpose of spawning. This is only partially the case. Although, in some instances, comparatively large ova have been found in the migrating eels, still none which have hitherto been examined have shown any considerable advance in the development of the ovum.

The important question, as to whether or not the eel takes food during its migration, was solved by Jacoby, who examined the stomachs of many hundreds of migrating eels. He invariably found the stomachs empty. He says that when the eels commence to migrate to the sea they take no food, just as other fish do during the spawning-period. 'The stomachs of those which do not migrate, both of those which are not yet able to migrate, and of those which never go to the sea, but spend their whole life in the lagoons, were more or less filled with remnants of food.'

Observers differ in opinion as to how far from the shore the spawning takes place. Pickard thought that the eel probably spawns in shallow, salt, or brackish water in harbours, and at the mouths of estuaries and rivers, where it is well known eels are speared in winter. It is clear, writes Norny, that the eels hibernate in winter to breed, the roe forms and matures during the period, and the young are hatched just at the end of this period. According to Jourdain, the eel which is ready for spawning descends to the sea, and remains in the neighbourhood of the coast. Jacoby, however, considered that the development of the reproductive organs takes place in the sea, not near the coast, but farther out in deep water. The latter view, to some extent, receives confirmation from the fact that the only ripe eel which is recorded as caught in salt water was captured 20 miles from land[1].

At present the balance of evidence seems in favour of assuming that the sexual migration of the eel is from one point of view the counterpart of that effected by the salmon. In the latter is seen a fish whose instinct impels it to migrate from the sea up the streams and rivers—making them a nursery for its offspring, and in the other case a fish guided by the same unerring instinct to leave the river-beds and migrate seawards—thereby taking advantage of the inaccessibility of the ocean to the many foes of its young. We may note that in each case man avails himself of the migratory instinct to successfully obtain a ready supply for his own needs.

Fishes having a migratory instinct similar to that which is shown to be most probable in the eel are known to naturalists as katadromous in contradistinction to the salmon whose habit is described as anadromous.

Another interesting conjecture suggests itself here, namely

[1] Feddersen says that the broad-nosed eel (pascuite) does not migrate to the sea, and breeds in fresh water. *Mittheil. des deutschen See-fischerei-vereins*, 1895.

—What becomes of the eels after spawning? According to several writers they never return to fresh water, but disappear altogether. The view of Siebold that the eel, like the lamprey, dies after the reproductive act, has been accepted by Jacoby, Cattie, Benecke and others. The ovaries of the migrating eel are very immature, and if the swarms of elvers, which ascend the rivers in May, are produced from the eels which migrated in the preceding autumn, the reproductive organs must arrive at a ripe condition with extraordinary rapidity. It is considered probable that the excessively rapid development of their organs of generation exhausts them to such a degree that they die a physiological death soon after they have spawned.

Amongst the numerous conjectures with regard to the origin of eels, there is one of early date which bids fair to have a sound basis of truth. There is a small group of peculiar little fishes, known as *Leptocephali,* and by various naturalists these have been supposed to be larval forms of members of the eel-family, or *Murænidæ.* The recent work of two Italian naturalists, Grassi[1] and Calandruccio, points to the conclusion that one of these *Leptocephali,* namely *L. brevirostris,* is transformed into the eel by a remarkable metamorphosis, which involves a reduction in length besides other changes. The key to this curious history was the discovery of the life-history of the conger (see Conger), and the Italian observers have followed nearly the whole process of metamorphosis, as they have in the conger, and have obtained a sufficient number of transitional forms to identify the eel, its præ-larva, and its larva.

Kaup long ago gave this diagnostic account of *Leptocephalus brevirostris*:—No dots; fourteen teeth in each jaw; small slender tail supported by visible rays; eyes black; total length 3·15 inches.—Locality, Messina.

Up till now this species of *Leptocephalus* with a single exception referred to below has not been found anywhere but at Messina, and the reason for this peculiar fact is probably

[1] *Proceed. R. S.* vol. 60, p. 260, Dec. 1896, and *Q. J. M. Sc.* Nov. 1896, p. 371.

that the larval form buries itself in the sand or mud and thus escapes the trawl. *Leptocephali* kept in confinement show a marked tendency to bury themselves and a liking for dark holes and corners, and the young eel dug out of the sand, already referred to, lends credence to this suggestion. We have also seen that many of the larval sand-eels remain embedded in the sand until the yolk is nearly absorbed, and this habit has prevented their capture up till now.

Another Italian naturalist, Raffaele, describes five different pelagic eggs of unknown parentage which he is inclined to regard as belonging to fishes of the eel-family; they have a large perivitelline space (cf. Long-rough dab) and a vesicular yolk, and the larvæ hatched from them have a large number of muscle-segments, a peculiar head and body, and a series of long teeth in the jaws. Grassi and Calandruccio claim to prove the suggestion of Raffaele that these are eggs and larvæ of *Murænidæ*.

One of these in particular, viz. Raffaele's undetermined species No. 10, which is devoid of oil-globules, has a diameter of 2·7 mm., and gives birth to what Grassi calls a præ-larva with long projecting teeth (Plate XX, fig. 6), and only 44 abdominal muscle-segments (myomeres), he associates with the eel. After twenty-four hours the larva (Plate XX, fig. 7) presents a trowel-shaped lower jaw with developing teeth. A further advancement is seen in Plate XX, fig. 8, which is a larva one day older than the preceding—in which the remarkable armature of temporary teeth is fairly developed. The anterior end (Plate XIX, fig. 9) of a more advanced, though probably not older larva, presents very large ear-capsules. All the foregoing were hatched by Mr Williamson towards the end of August, at Naples, and belong to Raffaele's species No. 8. As regards general form, teeth, and other points such larvæ are similar to that derived from egg No. 10 of Raffaele, which Grassi considers to be the egg of the eel. They differ, however, in the number of the abdominal segments, which are fewer in the larva of No. 10, and moreover the yolk of the latter has no oil-globules.

The preceding 'præ-larva' becomes, according to Grassi, a larva, viz. *Leptocephalus brevirostris* (fig. 42), a veritable metamorphosis, with the vent and the urinary opening near the tip of the tail, and with a body so translucent and peculiar that it was considered by Dr Günther, and others, to be an abnormality. A later stage of this condition is shown in fig. 43. It is remarkable that a large number of the *Leptocephali* were found in the stomach of the short sun-fish of the straits of Messina. Another change ensues, this larva, according to Grassi, becoming a hemi-larva, the two apertures last named moving forward to the anterior part of the body, which, instead of being deep and flattened like that of a ribbon-fish, becomes thickened and nearly round (fig. 44). By July the hemi-larva assumes the adolescent form. Like the American paradoxical frog, which is less than its tadpole, the larva and hemi-larva have a greater length of body than the young eel or elver into which they are transformed (fig. 45).

The post-larval leptocephaline stage does not occur in the nets in spite of the abundance of parent eels in British rivers, and this also may be accounted for by a burrowing habit, though the perfect transparency suggests a pelagic habit, and as a matter of fact a specimen of *L. brevirostris* has been caught in the North Atlantic.

Grassi and Calandruccio have been enabled to obtain specimens of *L. brevirostris* in two ways; firstly, by taking advantage of the remarkable currents at Messina, which at times stir up the sea-bottom and from it a number of deep-sea fishes and *Leptocephali*, and secondly, by opening the stomach of a certain deep-sea fish named the short sun-fish (*Orthagoriscus mola*), common in the straits of Messina. Their examination of *Leptocephalus brevirostris*, obtained in these ways, brought out a number of anatomical resemblances to the common eel. Of these we may note:

1. Vertebræ not exceeding 117 in the larva, enumerated by reference to the myotomes, spinal ganglia, etc.

2. Rays of pectoral fins the same in number.

3. No pigmentation in larva nor in 'elver.'

4. Presence of lateral branch of 5th cranial nerve.

They claim to have actually followed the transformation into the 'elver,' but they unfortunately did not preserve any at their first stage.

In the accompanying diagrams are shown the transition-stages already obtained. The first two give the appearance presented by *Leptocephalus brevirostris* at two different stages. Fig. 44 gives the transition form which may be caught during

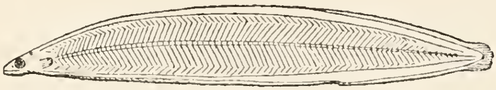


FIG. 42. *Leptocephalus brevirostris.* Nat. size. After Grassi.

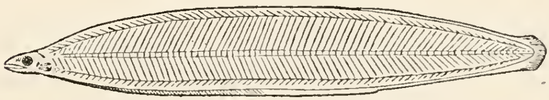


FIG. 43. The same *Leptocephalus* at a later stage. Nat. size. Grassi.

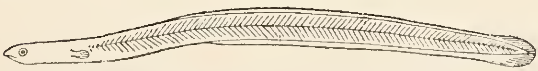


FIG. 44. Transition-stage or hemi-larva of the eel. Nat. size. Grassi.

FIG. 45. Young eel (elver) after the transformation. Nat. size. Grassi.

winter in the sea, and it presents intermediate characters between *Leptocephalus* and the 'elver' which is figured below it, and which can be caught in the course of migration from the sea into fresh water. There is no pigment, and the transformation to the normal elver of our rivers is effected by the development of definite black pigment and by a reduction in size. No young eel has been found, as already remarked, less than 5 cm. in length, but the colourless elver has an average length of 6·7 cms. Grassi sums up his observations as follows: '*Anguilla vulgaris,* the common eel, matures in the depth of the sea, where it acquires larger eyes than are ever observed in individuals which have not yet migrated to deep water, with the exception of the eels of the Roman cloacæ[1]. The abysses of the sea are the spawning-places of the common eel: its eggs float in the sea-water. In developing from the egg it undergoes a metamorphosis, that is to say, passes through a toothed præ-larval stage, then a larval form denominated *Leptocephalus brevirostris.* What length of time this development requires is very difficult to establish. So far we have only the following data: (1) *Anguilla vulgaris* migrates to the sea from the month of October to the month of January; (2) the currents, such as those of Messina, throw up, from the abysses of the sea, specimens which, from the commencement of November to the end of July, are observed to be more advanced in development than at other times, but not yet arrived at total maturity; (3) eggs, which according to every probability belong to the common eel, are found in the sea from the month of August to that of January inclusive; (4) the *Leptocephalus brevirostris* abounds from February to September. As to the other months we are in some uncertainty, because during them our only natural fisherman, the short sun-fish (*Orthagoriscus mola*), appears very rarely; (5) I am inclined to believe that the elvers ascending our rivers are already one year of age, and I have observed that in an aquarium specimens of *L. brevirostris* can transform themselves into young elvers in one month's time.'

The part of this curious life-history in which there is most room for doubt is the question as to the identity and habitat of the eggs of the eel.

The Conger. (*Conger vulgaris*, Cuv.)

This fish is a very near ally of the eel, and its reproductive organs are of a similar type. There is however an important difference in the habits of the two species; thus whilst the eel

[1] The large-eyed eels are familiar to us in the pond on the Isle of May, and occasionally elsewhere, so that Grassi's remark that this increase 'finds its physiological explanation in the circumstance that the eel matures in the depths of the sea' opens up some interesting questions.

undergoes in its lifetime a migration from the sea to the fresh-water lakes and rivers—eventually returning to the sea once more to fulfil the law of reproduction, the conger, on the other hand, never leaves the ocean and is essentially marine. The former appears to require the sudden change to a marine environment as a stimulus to the maturation of its reproductive organs, whilst the latter having a permanent marine habitat, is far more amenable to experimental research. It follows from this that naturalists who have attempted to solve the eel-problem have wisely led a flank attack upon its ally, the conger, and with such success that every step gained in our knowledge of the latter form appears to shed further light upon the former.

Several able observers, Hermes, Brock, Jacoby and others have given detailed descriptions of the organs of generation of the conger. Dr Otto Hermes in 1880 examined some congers which had died in the Berlin Aquarium and made the discovery of ripe spermatozoa in the milt (testes) of the male. This fact at once had its effect upon the 'eel question,' for, as already stated, Dr Syrski had described organs in the male eel (which have been known since as 'Syrski's organs'), which, he concluded from their position and relationship, were the testes of this fish (see Eel), and the organs which have a similar position in the male conger being shown to be testes we have been enabled to prove by deductive reasoning that Syrski's supposition was correct. According to Hermes each testis is a thin elongated organ suspended by a dorsal mesentery throughout the length of the body-cavity. The organ is lobed—in his figure there are five lobes on the right side and four on the left. From the base of each testis leads a closed spermatic duct or *vas deferens,* and the two join to open to the exterior behind the vent. This male conger was 28 inches in length. The female organs need not be here described in detail as they are closely similar to those of the eel, and the similarity extends to the difference in size between the sexes, the females being larger than the males. The eggs are shed into the abdominal chamber and then externally by the genital pore.

The conger is enormously prolific, the number of eggs in one individual varying at least from 8,000,000 to 3,000,000, and unlike the gadoids and other fish already described, all these eggs appear to ripen at the same time. The consequence is that there is an enormous distension of the ovaries and the pressure upon the surrounding organs appears, at least in confinement, to cause the death of the parent. The total weight of the ripe ovaries may considerably exceed one-third of the total weight of the fish ; in fact, Day records the death of a female conger in the Southport aquarium, which weighed $15\frac{1}{4}$ lbs. and the ovaries weighed no less than 7 lbs. From these and other facts it is assumed that the conger becomes sexually mature, only once, and perishes upon or immediately after the extrusion of the ova. Cunningham, experimenting upon captive congers in the Plymouth Laboratory, has brought additional evidence to bear upon this point, and he holds that the fishes which died at sexual maturity had undergone a peculiar degeneration of the tissues, involving a loss of teeth and a softening of the bony structures. He claims that this takes place to such an extent that, assuming a like phenomenon in a state of nature, the fish would be in an unfit state for capturing its prey and death by starvation would result. This may be so, but experiments upon fish in a state of captivity are occasionally misleading (see Chapter on Growth-Rate).

The facts, however, seem to favour the hypothesis that the conger reproduces but once, and dies shortly thereafter. A similar fate is believed to overtake the eel. S. Müller stated that the river-lamprey dies whilst spawning, and A. Müller maintained the same for the little lamprey, whilst Panizza observed that the sea-lamprey is brought up dead in numbers immediately after the spawning-period. These facts, if such they be, all strengthen the case for the conger; on the other hand, ripe congers are found to vary very much in size from 8 feet downwards quite apart from the sexual diversity in size.

Little definite is known concerning the spawning-period of the conger, indeed facts seem to point to an indefinite spawning-season, ripe females being found at nearly every month of the year. This, however, is largely conjectural. If such were really the case it would form evidence in favour of expecting that the conger lays its eggs on or in the sea-bottom and not pelagically, for in fish with pelagic eggs fertilization is ensured by vast masses of eggs and spermatozoa being set free in close proximity in the mid-water at the same time. Great numbers of each sex usually congregate together so that the limits of time and space being very confined, the probability of eggs avoiding fertilization is made as small as possible. Such limitations are obviously impossible in fishes which mature at various seasons of the year, for, even if congregations took place, only a small proportion of each sex would be ripe at a given time. These considerations are exaggerated by the extremely rapid and simultaneous ripening of the whole contents of the ovary. Other indirect evidence in favour of demersal spawning is found in the presence of certain secondary sexual characters. It has been pointed out above (see Dragonet) that the fishes with demersal eggs are those, as a rule, which show secondary sexual characters coupled with a tendency to 'pair.' We have seen that the common eel shows distinct secondary sexual features which are emphasised at the breeding season and the conger in this seems to resemble its ally. Mr Cunningham finds that—'in the female (conger) the outline of the head when looked at from above is triangular, the snout being pointed; in the male the same outline is much less pointed, the snout being distinctly blunter. Also in the female the dorsal surface of the snout in front of the eyes is arched, so that a transverse section of the dorsal surface is the arc of a circle; in the male the surfaces of the snout are flat, its sides above the mouth being perpendicular and the upper surface almost level, so that a transverse section forms three sides of a square.' The males also appear to be much darker on the ventral surface and usually to have more prominent eyes.

Thus the presence of secondary characters and the indefinite spawning-period point to either a demersal spawning-habit, *or* as in the case of the dragonet to a pairing instinct combined with a pelagic egg. This latter seems the more likely alternative when we take into consideration the enormous fecundity of the conger, a feature which is characteristic of fishes with a pelagic-spawning habit.

As regards the numerical relation of the sexes, Brock has found them about equal, but Cunningham is inclined to consider that the females are predominant, a feature of fishes with pelagic eggs, and certainly those tossed on shore during extremely cold weather are, as a rule, females. This opinion is, however, based upon the numerical superiority of females in a small number of congers of both sexes, none exceeding 2 feet 6 inches in length. He claims that 'all specimens over 2 feet 6 inches in length are females, and therefore, if the sexes were approximately equal in number we should find the males more numerous than the females amongst the specimens under 2 feet 6 inches'; but he has entirely overlooked another consideration. He finds that a male may become sexually mature as small as 18 inches in length and does not usually exceed 2 feet 6 inches, in fact his largest was 2 feet 2 inches; hence, in any district, the congers under 2 feet 2 inches will be immature males, mature or maturing males and immature females. 'The observed fact that both males and females cease to feed when their sexual organs *begin to ripen*, satisfactorily explains why it is that ripe specimens have never been obtained directly from the sea,' hence we may expect to catch only the quite immature males and the females, in the case under consideration, and leave unmolested the mature and maturing males, which will form a great proportion if not a majority of all those under 2 feet 6 inches. Under these circumstances a predominance of females has yet to be proved.

As regards the ripe eggs of the conger we know nothing as yet. Raffaele has described five unknown eggs which he conjectures to be those of the *Murænidæ*, or eel family. They are pelagic, and have a large perivitelline space. The larvæ hatched from them had a great number of muscle-segments and had long teeth (see the Eel). These may be murænoid eggs; whether one of them may be that of the conger has yet to be shown, pelagic and demersal eggs occur indiscriminately amongst the very nearest allies.

Grassi has attempted to show that the larvæ, hatched from the eggs here referred to, have essentially the characters of the *Leptocephali* mentioned below. He summarises the life-history of the muraenoids (leaving out the common eel) as follows:

'Females can only mature in very profound depths of the sea, that is to say, at least a depth of 500 metres. This fact I established by finding well-known deep-sea fishes together with *Leptocephali*, ripe *Muraenae*, and quite ripe eels. The females of those species which do not live at this depth must therefore migrate to it. The male, however, can mature at a smaller depth and therefore they migrate into the greater depth when they are already mature. Fertilization takes place at great depths: the eggs float in the water; nevertheless they remain at a great depth in the sea, and only exceptionally, for unknown reasons, some of them mount to the surface[1].'

The earliest free form definitely connected with the conger is one of a small group of fishes known as the *Leptocephali*. This group has a history in some respects closely similar to that of the mackerel-midges: like them they were first described as adult forms or abnormalities, and later, with increase of knowledge, they have been shown to be the young stages of well-known species. The first recorded specimen of British leptocephalid was caught by a Mr William Morris, in the neighbourhood of Holyhead. This fish was given the name of 'the Morris' by the celebrated naturalist, Pennant, and *Leptocephalus morrisii* by the Dutch observer, Gronow, by whom it was described. The description has proved to be inaccurate and we need not detail it here. These events took place in the middle of the eighteenth century and in the next fifty years several isolated specimens appear to have been caught from time to time, apparently on the bottom.

Early in the 19th century two specimens caught at the surface fell into the skilful hands of the late Colonel Montagu, whose name is also connected with the history of the mackerel-midges. He gave a correct description of them. Couch, at a later date, obtained and described four specimens, naming them *Ophidium pellucidum*, but afterwards establishing their identity with *Leptocephalus morrisii*. Prof. Carus in a short article upon the group *Leptocephalus* pointed out reasons for believing

[1] *Op. cit.*

that it comprised a number of young stages of other species, but it was left to the American ichthyologist, Gill, upon evidence derived from a comparison of the anatomical resemblances between the two, to definitely formulate the suggestion that *Leptocephalus morrisii* was the larval form of the conger.

A *Leptocephalus* (probably a young conger) in the St Andrews University Museum, caught in 1869 on the western coast, has been figured here (Pl. XIX, fig. 6) to show the appearance of this interesting little form, and the description of another, caught in June 1890, in Loch Scridain, is as follows:— 'Young conger, 80 mm. In this the lateral line has a row of black chromatophores of the ordinary structure from behind the pectorals to the tail, ventrally a double row (somewhat widely separated), of black chromatophores to the commencement of the anal fin, where the rows approach each other, and have between them a median row at the base of the fin. The dorsal comes far forward, reaching within $\frac{7}{8}$ in. of the tip of the snout, but still far behind the tip of the pectorals. No black pigment-specks occur at the base of this fin. Both anal and dorsal fins have permanent rays. The tail resembles that of the adult. The gill-slits are almost ventral. The eye is larger than in the common eel of the same size, and the shape of the body different[1].'

Six years after Gill's discovery, viz. in 1870, his theory was accepted by Dr Günther, the celebrated ichthyologist[2], but with a very peculiar modification. In his *Catalogue of Fishes* (British Museum) he puts forward the hypothesis that the leptocephaline stage is not a normal larval (or more accurately post-larval) conger but is arrested in its development at an early stage, so that it increases in bulk and continues to develop in some particulars whilst other organs remain in a rudimentary condition. Under these circumstances, he supposed that the *Leptocephalus* was incapable of transformation into a conger. If, he suggests, the normal young conger is nursed in a littoral environment then very young stages carried out by accident to the open sea and submitted to

[1] W. C. M. *9th S. F. B. Report*, p. 336.

[2] To whom one of us gave his collection of *Leptocephali* in 1868.

pelagic environment may, under such abnormal conditions, become leptocephaline in appearance. As recently as in 1880 he still upheld the same theory in his *Introduction to the Study of Fishes*. His main point appears to be the fact that young congers are found, which are considerably smaller than many specimens of *Leptocephalus morrisii*; this is, to some extent, accounted for by a reduction in size during the metamorphosis.

At as recent a date as 10 years ago, Professor Delage of Paris, made the announcement that he had succeeded in following the whole transformation from *Leptocephalus* to conger. Two young *Leptocephali* were captured in February, and one of these was kept in confinement till September. The earliest changes commenced in May and consisted in the appearance of a black pigment in the skin and of a thin silvery rudiment of the air-bladder. The general shape of the body became more cylindrical, and the head more blunt and square, and these changes proceeded little by little till in July the ribbon-shaped transparent larva was completely transformed into a little conger of 3·5 inches having most of the adult characters. It is much to be regretted that the dimensions of the *Leptocephalus* were not given, so that in this case there is no evidence of the reduction in size which is said to take place.

This discovery, though for some time unsupported, has now been amply verified by two Italian observers, Professor Grassi and Dr Calandruccio, to whose work reference has already been made (see 'the Eel'). They worked at Messina, at which place, on account of the currents mentioned, *Leptocephali* are found in great abundance. Apart from other important results, they have shown that the two forms *Leptocephalus morrisii* and *L. punctatus* are stages in the life-history of the conger. They suggest that the scarcity of *Leptocephali* upon British coasts is due to the fact that they may bury themselves in the sand or mud. We are now in a position to trace the details of what is known of the development. As a whole, the *Leptocephali* are elongated, ribbon-like fishes with a very small head, pellucid and silvery, no trace of reproductive organs, no air-bladder, no ribs and hardly any ossifications.

The earliest stage of a conger made known to us by the Italian observers is of this form and differs from the next stage in the black dots on the lateral line being confined to the posterior end of the body and in the presence of long and prominent teeth. By an extension forwards of the dots and a replacement of the larval by the adult teeth, the stage hitherto known as *Leptocephalus morrisii* is reached. Kaup diagnoses this form as follows:—'A blunt head, scarcely visible teeth; lateral line, belly, and anal fin dotted with black points; tail pointed; greatest height one-ninth of the total length.' As the metamorphosis proceeds, a stage is reached, identical with *Leptocephalus punctatus*; this is also diagnosed by Kaup as:—'A round vermiform body; points along the lateral line, oblique pairs of dots along the edge of the belly; anus before the middle of the body, and a row of indistinct points on the anal fin.—Messina.'

From this stage, the metamorphosis proceeds; the most conspicuous feature is a great reduction in size—*Leptocephali* of 5 inches may become young congers of no more than 3 inches. Together with this reduction in size, there is an alteration in the position of the vent, a reduction of the hypertrophied gelatinous skeleton, and a development of dark pigmentation. Cunningham finds young congers in the Cornwall district as small as 8⅖ inches in length, and he remarks upon the sparsity of black pigment in specimens from this size to 15 inches. They occur on the east coast of a length of 15 inches in March, the black pigment is then copious in the dorsal region.

Conger of 8, or even 9 feet are common, and in these, if Cunningham's views are to be accepted, maturation of the sexual elements must be postponed till far beyond the third year.

Concluding Remarks upon the Murænoids.

From the preceding accounts of our present state of knowledge concerning the life-histories of the eel and the conger, it will be seen that the mystery attaching thereto is on a fair way to being cleared up. At the same time a great deal yet remains to be done. The first step in the progress was made by Delage's discovery of the transformation of *Leptocephalus morrisii* into a young conger, and the obvious conclusion therefrom was that the common eel had also a leptocephaline stage.

Grassi and Calandruccio have pointed out the particular form (*L. brevirostris*), and, in addition, have been enabled to confirm and extend the observations of Delage upon the leptocephaline stages of the conger. Whilst according due merit to the able researches of these two naturalists, we consider that the other points with respect to the development of the eel are not yet proved.

The eggs described by Raffaele, with vesicular yolk (a character found in some clupeoids) and a large perivitelline space (a feature shared by the eggs of the pilchard and the long-rough dab) and the larvæ hatched therefrom, have yet to be proved to be those of muræenoids. They appear to be perfectly normal pelagic eggs with surface-habitat, and give no indication of 'floating at a great depth.'

We still require definite answers to the following:—

1. When and where do eels and congers normally spawn?

2. Does the reproductive act involve immediate death to the parent?

3. What are the appearance and structure of the eggs of the conger and the eel?

4. Are they pelagic or demersal? If the former, are they of surface- or deep-sea habitat?

5. What is the normal habitat of the *Leptocephali*, at least *L. brevirostris* and *L. morrisii*? Why are they not found in abundance on our coasts?

6. Do abnormal *Leptocephali* occur, or, indeed, is a leptocephaline stage a *normal* part of the muræenoid life-history at all?

It may be that the complete memoir promised by the Italian naturalists may clear up some of these points and may convert hypotheses with varying degrees of probability into ascertained facts. The investigation of the life-history of the eel, unlike that of other marine fishes, has suffered from a plethora of workers whose faculty of imagination has enabled them to play upon the credulity of others, so that it behoves those who are attempting to explore these most intricate of nature's paths, the life-histories of the marine food-fishes, to demand that every step in advance should be made by the aid of well-proved observations.

SYNOPTICAL TABLE

OF

EGGS OF MARINE FISHES.

SYNOPTICAL TABLE OF THE EGGS OF MARINE FISHES.

Species	Popular name of Species	Diam. (Average) of egg in mms.	Diam. (Average) of oil-globules in mms.	Pelagic or Demersal	Spawning-period	Leading specific characters
Boccus labrax, L.	Sea-perch	1·15—1·2	·33—·36	P.	Jan.—Mar.	Single large o. g. Black and yellow pigment.
Serranus cabrilla, L.	Smooth serranus	·9	·15	P.	May—Aug.	Black and yellow pigment in embryo.
Mullus barbatus, Cicer.	Red mullet	·93	·23	P.	May—Aug.	Vesicular yolk, porous capsule, only black pigment.
Sebastes marinus, L.	Norway haddock	—	—	—	—	Viviparous.
Cottus scorpius, L.	Sea-scorpion	1·5—2	·015	D.	Feb.—Mar.	Orange, red, straw, masses, capsule with linear punctures, and facetted.
Cottus bubalis, Eu.	Father-lasher	1·7—1·88	·22 (hatched)	D.	April	Golden or straw, masses, many o. gs.
Cottus quadricornis, L.	Four-horned bull-head	—	—	D. (?)	—	Masses (?).
Trigla cuculus, L.	Red gurnard	1·47—1·61	·33	P.	June—July	Copper-coloured oil-globule.
Trigla gurnardus, L.	Grey gurnard	1·42—1·52	·125	P.	April—Aug.	Single smoky o. g.
Agonus cataphractus, L.	Armed bull-head	1·75—1·9	·54	D.	Jan.—April	Dull golden masses, capsule with linear punctures.
Lophius piscatorius, L.	Frog-fish	2·28	·53	P.	—	Violet or black mucoid sheets.
Trachinus vipera, Cuv.	Lesser weever	1·25—1·37	11 to 30 small	P.	April—July	Greenish-yellow o. gs.
Scomber scombrus, L.	Mackerel	1·22	·32	P.	June—July	Colourless o. g., 'green.' Yellow and black pigment.
Caranx trachurus, Lac.	Horse-mackerel	·84	large	P. (?)	June—July	Proportionally large o. g.
Capros aper, L.	Boar-fish	·97—·98	·19	P.	July—Aug.	Sparse black pigment.
Zeus faber, L.	John Dory	—	—	P. (?)	June-Aug. (?)	
Gobius minutus, Pall.	Freckled goby	1·2—1·4	small (many)	D.	May—June	Pyriform, attached to shells of *Mya*, *Lutraria*, *Solen*, etc. in groups.
Gobius niger, L.	Black goby	1·5	many small	D.	May	Spindle-shaped, fixed to seaweeds, mussels, wood-work, etc.
Gobius flavescens, Fab.	Two-spotted goby	·8 (breadth ·6)	many small	D.	May—Aug.	Reddish-brown o. gs., fixed to various objects. Oval egg.
Callionymus lyra, L.	Dragonet	·686	none	P.	May—Aug.	Capsule with hexagonal markings.
Cyclopterus lumpus, L.	Lumpsucker	2·54	·041 (largest)	D.	Feb.—July	Reddish, straw, greenish, masses in rock-crevices, many o. gs., capsule with large and small punctures.
Cyclogaster liparis, Fl.	Common sea-snail	1	—	—	May	Light carmine (Ekström).
Cyclogaster montagui, Don.	Montagu's sucker	1·143	·208	D.	Jan.—July	Small masses on zoophytes. Straw to pink yolk and o. gs. Areolar capsule.
Lepadogaster bimaculatus, Don.	Bimaculated sucker (Two-spotted)	1·37	—	D.	June—July	Singly in bivalve shells.
Anarrhichas lupus, L.	Wolf-fish (Cat-fish)	5·5—6	1·7	D.	Oct.—Feb.	Pale straw opalescent masses. Thick punctured capsule, great size.
? *Blennius ocellaris*, L.	Butterfly blenny	1·2	many small	D.	—	Orange-red yolk, attached to bone.
Chirolophis galerita, L.	Yarrell's blenny	1·9 (ovarian)	?	D. (?)	—	
Blennius pholis, L.	Shanny	2·54	—	D.	June	Amber, in rocky crevices, single layer.
Pholis gunnellus, L.	Gunnel	1·092	·3	D.	Dec.—March	Straw, masses, in rocks.
Zoarces viviparus, L.	Viviparous blenny	—	—	—	Birth in winter	Viviparous.
Mugil capito, Cuv.	Grey mullet	1	·2	P.	June—Aug.	Black pigment only.
Gasterosteus spinachia, L.	Fifteen-spined stickleback	2·159	many small	D.	May—June	In seaweed nests, many o. gs.
Labrus bergylta, Asc.	Ballan wrasse	1·01—1·13	—	D.	April—July	Nests.

Crenilabrus melops, L.	Conner (Corkwing wrasse)	·78	none	P.	June	Colourless, no o. g.
Ctenolabrus rupestris, L.	Jago's Goldsinny	·835	none	P.	June	Translucent yolk, black pigment.
Coris julis, L.	Rainbow wrasse	·6—·7	·16—·18	P.	Spring—Summer	
Gadus callarias, L.	Cod	1·397	none	P.	Feb.—May	Delicate thin capsule, black pigment, barred.
Gadus æglifinus, L.	Haddock	1·473	none	P.	Jan.—May	Ditto, black pigment.
Gadus luscus, Will.	Bib	1·05—1·15	none	P.	Jan.—Feb.	Ditto.
Gadus minutus, L.	Poor-cod	·906	none	P.	Mar.—June	Ditto, black and yellow pigment.
Gadus merlangus, L.	Whiting	1·206	none	P.	Mar.—June	Ditto, yellow pigment.
Gadus virens, L.	Green cod	1·161	none	P.	Jan.—April	Ditto, black pigment.
Gadus pollachius, L.	Pollack	1·143	none	P.	Feb.(?)—May	Ditto, black pigment.
Gadus esmarkii, Nil.	Norway pout	·98	none	P.	April	Ditto, larva like whiting.
Molva molva, L.	Ling	1·08	·4	P.	April—June	Smoky oil-globule, tough capsule, greenish yellow.
Onos mustela, L.	Five-bearded rockling	·72	·0825	P.	April—Aug.	Yellowish o. g., corrugated capsule.
? *Onos cimbrius*, L.	Four-bearded rockling	·82	size?	P.	March	Black pigment early, single o. g.
Onos tricirratus, Brünn.	Three-bearded rockling	·74	·218	—	Nov.—Jan.	Yellow o. g.
Raniceps raninus, L.	Lesser fork-beard	—	—	P. (?)	July—Aug.(?)	
Brosmius brosme, Ascan.	Torsk	1·333	·25	P.	April—May	Pale red-brown o. g., tough capsule.
Ammodytes lanceolatus, Les.	Greater sand-eel	·762 (ovarian)	·195	D. (?)	May, July —Dec.—	Greenish o. g., thick adhesive capsule.
Ammodytes tobianus, L.	Lesser sand-eel	·8 (dead)	·2 (dead egg)	D. (?)	May, July -Dec., Jan.	Honey-coloured o. g., adhesive capsule.
Hippoglossus vulgaris, Fl.	Halibut	3·42—3·76	none	P.	Ap.—May (?)	Thin capsule, large size.
Drepanopsetta platessoides, Fab.	Long-rough dab	1·79—1·87	none	P.	March—May	Large perivitelline space.
Bothus maximus, Will.	Turbot	1·0287	·21	P.	June—July	Single o. g., wrinkled capsule.
Bothus rhombus, L.	Brill	1·33	·23	P.	Mar.—July	Ridged capsule, o. g. with faint yellow rim.
Zeugopterus punctatus, Bl.	Müller's topknot	1·067	·2	P.	May—July	Early yellowish pigment, single o. g.
Rhombus norvegicus, G.	Norwegian topknot	·9	·15	P.	July	Single o. g.
Lepidorhombus whiff, Walb.	Sail-fluke	1·43	·3048	P.	March—May	Capsule corrugated and striated, black pigment only.
Platophrys laterna, Walb.	Scald-fish	0·659	—	P.	May—Aug.	
Pleuronectes platessa, L.	Plaice	1·65—1·79	none	P.	Jan.—May	Striated capsule, large size.
Pleuronectes microcephalus, Don.	Lemon-dab	1·346	none	P.	April—Aug.	Thick ridged capsule.
Pleuronectes cynoglossus, L.	Witch	1·15—1·19	none	P.	May—July	Striated capsule.
Pleuronectes limanda, L.	Dab	·838	none	P.	Mar.—June	Small, lemon-yellow pigment.
Pleuronectes flesus, L.	Flounder	·965	none	P.	Feb.—July	Yellow and black pigment.
Solea vulgaris, Qu.	Sole	1·181—1·295	many ·004 ·01	P.	April—Aug.	Many small o. gs.
? *Solea variegata*, Don.	Variegated sole	1·36	many	P.	April—May	Many rather large o. gs., scattered singly.
Solea lutea, Risso	Little sole (Solenette)	·762	many ·1 (largest)	P.	April—May	Ditto.
Rhamphistoma belone, L.	Gar-pike	—	—	D.	May—July (?) (April)	Adhesive filaments.
Scombresox saurus, Walb.	Skipper	—	—	D.	—	Adhesive filaments.
Engraulis encrasicolus, L.	Anchovy	1·25 1·15	none	P.	May—Sept.	Ovoid (short diam. = ·5 mm.). Reticulated yolk.
Clupea harengus, L.	Herring	1·54	none	D.	(Varying)	Masses on foreign bodies, reticulated yolk.
Clupea sprattus, L.	Sprat	1·016	none	P.	Ap.—July	Thin capsule, reticulated yolk.
Clupea pilchardus, Walb.	Pilchard	1·5—1·7	·16	P.	—	Large perivitelline space, reticulated yolk.
Clupea alosa, L.	Allis shad	?	—	D.	—	Ditto. Ditto.
Clupea finta, Cuv.	Twaite shad	4·5	—	D.	—	Ditto. Ditto.
Anguilla vulgaris, Tur.	Eel	?	?	?	?	?
Conger conger, Cuv.	Conger	?	?	?	?	?

APPENDIX.

ON THE FERTILIZATION AND TRANSMISSION OF LIVING PELAGIC (FLOATING) AND OTHER EGGS OF BONY FISHES.

Though living adult fishes should always be chosen for the supply of eggs and milt, yet satisfactory results can be obtained from those which have been dead for some time. The collector therefore need not despair of recently dead fishes. By gentle pressure along the belly in the direction of the vent the transparent ripe eggs readily escape into a vessel of clean sea-water. If too much pressure be applied, unripe eggs, which are easily recognized by their opacity, are extruded, and they at once go to the bottom of the vessel. In the same way the milt of the male (a whitish creamy fluid) is gently squeezed out, and a very little allowed to drop into the vessel of sea-water amongst the eggs. Care should be taken not to add too much milt, as it renders the water impure during a journey, and thus causes the death of the eggs at an early stage. It is surprising to find how little milt will suffice to fertilize thousands of eggs in a large vessel.

Living eggs are at once distinguished from dead eggs by their buoyancy and glassy translucency. Unhealthy eggs become slightly milky and then wholly opaque. No reliance can be placed on eggs showing the faintest trace of this condition.

A few minutes may be allowed to elapse before measures are taken for renewing the sea-water and removing *débris* and dead eggs, meanwhile the vessel should remain at rest. If the eggs are very buoyant they may be collected at the surface with a shallow scoop of horse-hair or any similar instrument—such as a large spoon, a hand-net or a saucer, and placed in perfectly cool sea-water in a clean vessel, and this may be repeated several times till the experimenter is satisfied that he has removed all sources of contamination—such as milt, fluids from the fish, shreds of membrane and dead eggs. It is in the earlier stages of development that the greatest care is necessary. It may be, in some cases, that the upper layer of the water containing the floating eggs can best be manipulated by pouring it on a piece of clean cheese-cloth slightly dimpled into a funnel-shape, or into a hand-net. The eggs are thus caught and easily transferred to clean water, the *débris* being left at the bottom of the old vessel. It is an advantage also to wash the eggs in the sea when a net is employed in the foregoing operations.

Having thoroughly cleansed the eggs and water, the former may now be placed in clean earthenware jars, such as are made for jam (about 5—6 inches in diameter × 8 in. deep, with a shoulder and an aperture of $3\frac{1}{2}$—$3\frac{3}{4}$ in.), and not more than 100 of the healthiest should be put in each vessel if the journey will occupy several days. The vessel should be only three-quarters full of sea-water (best taken far from land), and the aperture is then tied over with clean cheese-cloth. Such jars can always be carried to sea or obtained in any town or village, and should have a piece of stout string tied round the neck with a loop for a handle. No packing-box is needed. The eggs are safer in the free jar both in regard to aeration and temperature.

These jars, containing rare eggs, should then be forwarded by the fastest train to the St Andrews (Gatty) Marine Laboratory with the hour and date of fertilization, locality and name of sender. A caution to keep the jar cool is also important. No hesitation need be felt about distance. Similar jars have carried living eggs from Shetland, from Gairloch, Ross-shire, from the Channel Islands and elsewhere to St Andrews. It would of course be unnecessary to send eggs, the development of which is already known in every detail (vide the various species).

Besides forwarding the eggs at an early stage, it is a wise precaution to retain some until the eyes of the little fish inside the egg are just visible. These should then be sent in clean water as before. On many occasions the latter alone have survived a long journey, as might have been expected from previous experience with the eggs of the salmon. Eggs with advanced embryos withstand many vicissitudes both in regard to temperature and impurity of environment.

Amongst the fertilized pelagic eggs which would be welcomed at St Andrews are those not described in this work, or only briefly alluded to, such as the eggs of the sea-perch, the various breams, greater weever, Spanish mackerel, spotted dragonet, poutassou, pollack, Norway pout, hake, three-bearded rockling, four-bearded rockling, tadpole-fish, halibut, various topknots, brill and anchovy.

Of other eggs both demersal (that is, occurring in masses or singly on the bottom) and pelagic yet required for examination are those of Murray's gurnard, tunny, maigre, hair-tail, *Aphya*, Nilsson's goby, common sucker, the various blennies, *Lumpenus*, deal-fish, oar-fish, sand-smelt, thick and thin-lipped grey mullets, the wrasses, bearded ophidium, smooth sand-launce, *Argyropelecus*, argentine, skipper, shads, trigger-fish, the sun-fishes, eel and conger. The demersal eggs of such as the common wrasse would live for several days amongst moist sea-weeds loosely put around them, if the eyes of the embryos were coloured. The sea-weeds must not be packed tightly around the eggs, else putrefaction will ensue. Examples of eggs of any kind may be sent by post in a fresh condition.

Even though it were impossible to procure fertilized eggs, yet the transmission, in sea-water, of the ripe eggs of any form not described in this work would be valuable. In the same way the transmission of a little ripe milt in a moist tube by post would also aid in elucidating unknown life-histories of fishes.

Where larval fishes are encountered a sketch and an explanatory note should be made of their shape and colours. If conveniences for following their growth are not at hand, they then, if living, may be sent in earthenware jars partly filled with sea-water, or preserved in strong spirit. Young fishes of all kinds should be transmitted fresh, or killed with corrosive sublimate solution and placed in strong alcohol, then put in a bottle, and the spirit changed within 24 hours. Care should be taken not to place too many specimens in each bottle. A fresh fish may be transmitted by post in time to have its colours and general contour examined.

PLATE I.

Fig. 1. Egg of Red Mullet, *Mullus barbatus*. F. Raffaele.

2. ,, ,, Sea-perch, *Boccus labrax*. F. Raffaele.

3. ,, ,, Smooth Serranus, *Serranus cabrilla*. F. Raffaele.

4. ,, ,, Long-spined Bullhead, *Cottus bubalis*. W. C. M.

5. ,, ,, Sea-scorpion, *Cottus scorpius*. W. C. M.

6. Mass of eggs of Sea-scorpion, *Cottus scorpius*. E. E. Prince.

7. Egg of Pogge, *Agonus cataphractus*. E. E. Prince.

8. Reticulations of egg-capsule of Pogge, *A. cataphractus*. E. E. Prince.

9. Egg of Grey Gurnard, *Trigla gurnardus*. E. E. Prince.

10. ,, ,, Red Gurnard, *Trigla cuculus*. E. W. Holt.

11. ,, ,, Frog-fish, *Lophius piscatorius*, showing embryo. From a spirit-specimen. W. C. M.

12. Anterior region of embryo in egg of ditto. A. Agassiz.

13. Egg of Boar-fish, *Capros aper*. J. T. Cunningham.

14. Egg and contained larva of Lesser Weever, *Trachinus vipera*. July 28, 1891. E. Corbin.

15. Egg of Dragonet, *Callionymus lyra*. July 2, 1894. J. R. Tosh.

16. Egg and contained larva of Mackerel, *Scomber scombrus*. E. W. Holt.

17. Mass of eggs of Wolf-fish, *Anarrhichas lupus*. Enlarged. W. C. M.

Plate I.

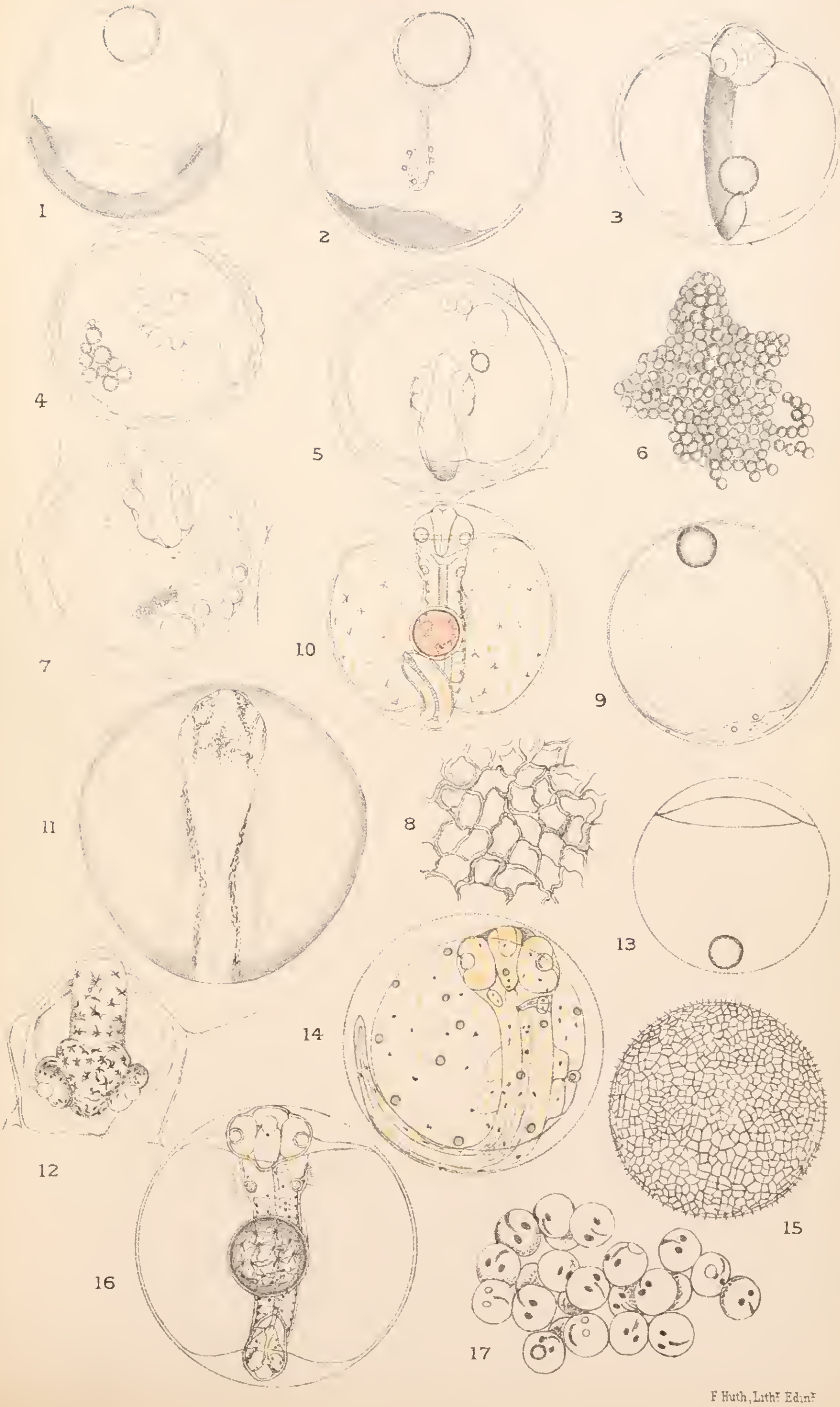


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PLATE II.

Fig. 1. Egg of Lumpsucker, *Cyclopterus lumpus.* E. E. Prince.

2. Eggs of Lumpsucker, *Cyclopterus lumpus.* E. E. Prince.

3. Egg of Grey Mullet, *Mugil capito.* F. Raffaele.

4. ,, ,, Gunnel, *Pholis gunnellus.* Jan. 9, 1890. W. C. M.

5. ,, ,, Bimaculated Sucker, *Lepadogaster bimaculatus.* E. W. Holt.

6. Egg and contained larva of Freckled Goby, *Gobius minutus.* C. J. Petersen.

7. Eggs of Freckled Goby, *Gobius minutus.* E. W. Holt.

8. Eggs of Freckled Goby, *Gobius minutus*, on *Mya.* C. J. Petersen.

9. Egg of Montagu's Sucker, *Cyclogaster Montagui.* W. C. M.

10. Eggs of Montagu's Sucker, *Cyclogaster Montagui.* E. E. Prince.

11. Egg and embryo of Black Goby, *G. niger.* C. J. Petersen.

12. Eggs of ditto in spirit, enlarged. W. C. M.

13. Egg of Doubly-spotted Goby, *G. flavescens* (olim *Ruthenspari*). C. J. Petersen.

14. Eggs of ditto, on *Laminaria.* C. J. Petersen.

Plate II.

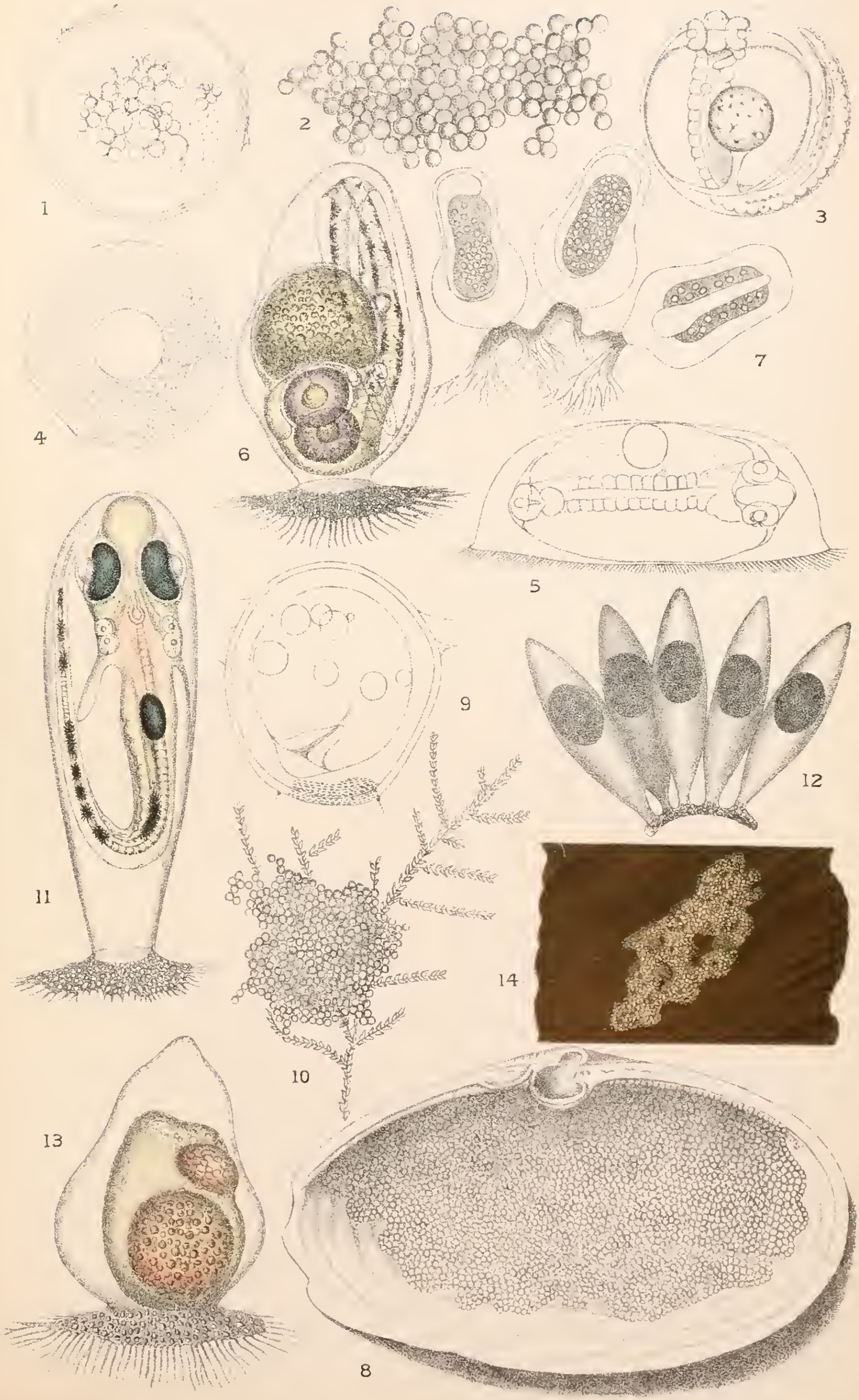

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PLATE III.

Fig. 1. Egg of Haddock, *Gadus æglifinus*, 3rd day. E. E. Prince.

2. Empty egg-capsule of Haddock. E. E. Prince.

3. Larval Haddock, emerging from egg-capsule. E. E. Prince.

4. Egg of Hake, *Merluccius vulgaris*. F. Raffaele.

5. Eggs of Ling, *Molua molva*, floating at the surface of still water. W. C. M.

6. Unripe egg of Poor-cod, *Gadus minutus*. June 3, 1892. W. C. M.

7. Egg of Pollack, *Gadus pollachius*, 4th day. W. C. M.

8. ,, ,, Green Cod, *G. virens*, 9th day. Feb. 24, 1894. W. C. M.

9. ,, ,, Rockling, *Onos tricirratus*. March 9, 1891. W. C. M.

10. ,, ,, ditto. June 24, 1893. W. C. M.

11. ,, ,, Torsk, *Brosmius brosme*. May 28, 1892. W. C. M.

12. ,, ,, ditto, later stage. W. C. M.

13. ,, ,, Larger Sand-eel, *Ammodytes lanceolatus*, only a portion shaded. June 6, 1891. W. C. M.

14. Egg of Larger Sand-eel, *Ammodytes lanceolatus*. W. C. M.

15. ,, ,, Lesser Sand-eel, *A. tobianus*. W. C. M.

16. ,, ,, Larger Sand-eel, *A. lanceolatus* (ovarian). W. C. M.

17. ,, ,, ditto, more advanced, showing micropyle. W. C. M.

18. Eggs of Halibut, *Hippoglossus vulgaris*, dead, not fresh. Natural size. W. C. M.

19. Egg of Long-Rough Dab, *Drepanopsetta limandoides*, before fertilisation. W. C. M.

20. Egg of ditto, after fertilisation. Reduced. W. C. M.

21. ,, ,, ditto, with embryo, zona removed. W. C. M.

22. ,, ,, Turbot, *Bothus maximus* (ovarian). June 7, 1891. W. C. M.

23. Egg of ditto, extruded but unfertilised. W. C. M.

24. ,, ,, ditto, advanced. W. C. M.

25. ,, ,, Hybrid between Brill and Turbot, advanced. E. E. Prince.

Plate III.

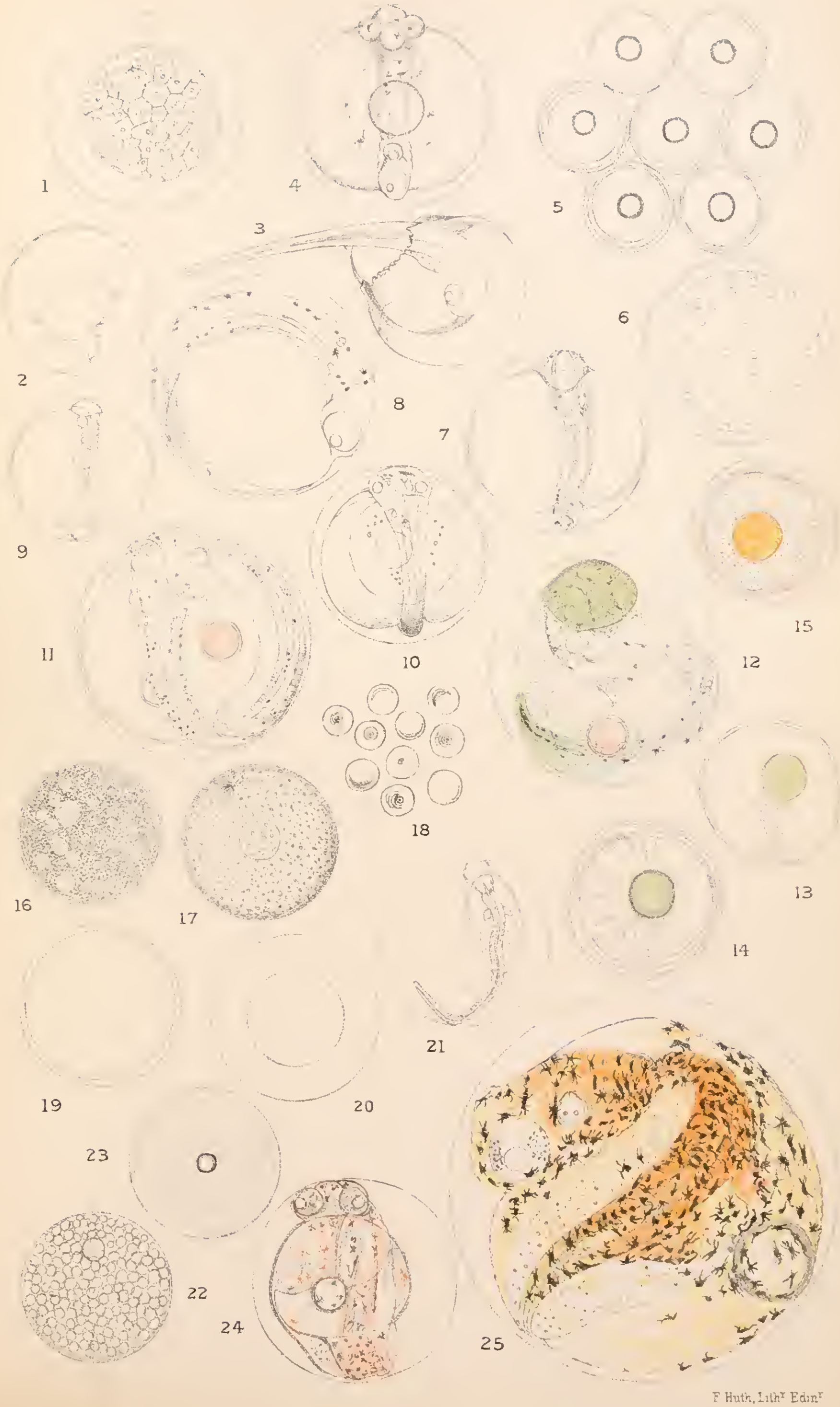

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PLATE IV.

Fig. 1. Egg of Brill, *Bothus rhombus*, irregular segmentation. May 24, 1892. W. C. M.

2. ,, ,, ditto. May 25, 1892. W. C. M.

3. ,, ,, ditto. May 27, 1892. W. C. M.

4. ,, ,, Sail-fluke, *Lepidorhombus whiff.* W. C. M.

5. ,, ,, Topknot, *Zeugopterus sp.* July 9, 1891. W. C. M.

6. ,, ,, Topknot, *Z. punctatus*, unfertilised. W. C. M.

7. ,, ,, Topknot-like form, advanced. E. E. Prince.

8. ,, ,, Sole, *Solea vulgaris*, from above (floating). W. C. M.

9. ,, ,, ditto, lateral view. W. C. M.

10. ,, ,, ditto, later stage (pigmented yolk). W. C. M.

11. ,, ,, Solenette, *Solea lutea*. July 11, 1890 (early stage). W. C. M.

12. Egg of Variegated Sole, *Solea variegata* (embryo outlined). July 13, 1890. J. T. Cunningham.

13. Egg resembling that of Solenette, numerous minute oil-globules. April 10, 1892. W. C. M.

14. Egg of Plaice, *Pleuronectes platessa*, with advanced embryo. April 20, 1886. E. E. Prince.

15. Egg of Lemon Dab, *P. microcephalus*, late stage. July 15, 1890. (The colour here is diagrammatic.) W. C. M.

16. Capsule of egg of ditto, showing cross-ridges. W. C. M.

17. Portion of capsule of egg of ditto, highly magnified. W. C. M.

18. Egg of Dab, *P. limanda*. E. E. Prince.

19. ,, ,, Sprat, *Clupea sprattus*. E. E. Prince.

20. Egg like that of Dab. June 11, 1892. W. C. M.

21. Egg of Anchovy. F. Raffaele.

22. ,, ,, ditto, advanced. F. Raffaele.

23. ,, ,, Pilchard, *Clupea pilchardus*. F. Raffaele.

24. ,, ,, Herring, *Clupea harengus* (first furrow). C. Kupffer.

Plate IV.

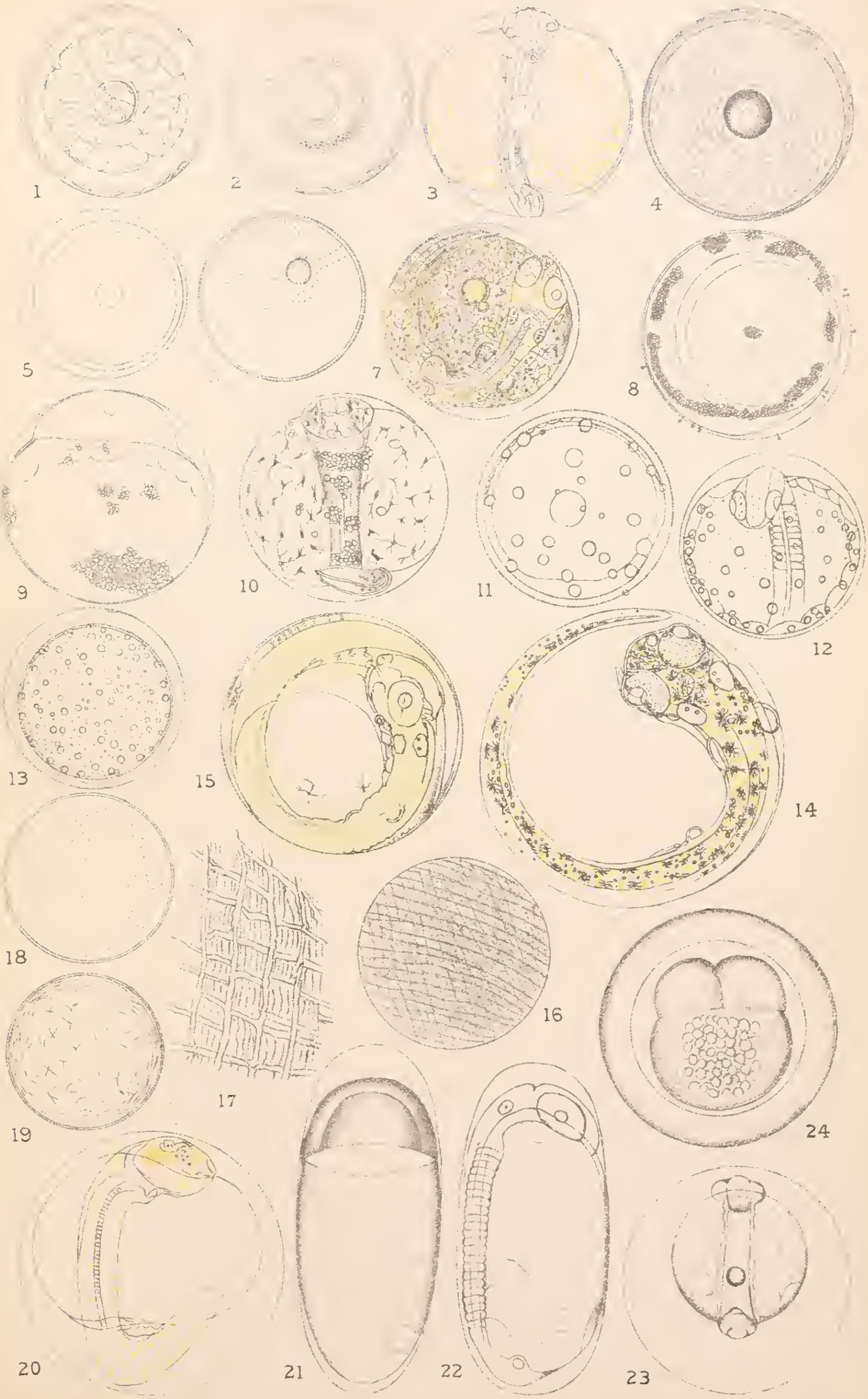

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PLATE V.

Fig. 1. Newly hatched larva of Sea-perch, *Boccus labrax.* F. Raffaele.

2. Larval Smooth Serranus, 4 or 5 days old. F. Raffaele.

3. Newly hatched larva of Smooth Serranus, *S. cabrilla.* F. Raffaele.

4. Newly hatched larval Red Mullet, *Mullus barbatus.* F. Raffaele.

5. Larval Red Mullet, 6 or 7 days old. F. Raffaele.

6. Larval Sea-perch, 12 to 15 days old. F. Raffaele.

7. Advanced larval Sea-scorpion, *Cottus scorpius.* April 13, 1886. E. E. Prince.

8. Young Sea-scorpion, *C. scorpius*, about $\frac{3}{5}$ inch. May 6, 1887. E. E. Prince.

9. Newly hatched larval Long-spined Bullhead, *Cottus bubalis.* E. W. Holt.

10. Post-larval Bullhead, *Cottus sp.*, enlarged (about 9 mm. long). W. C. M.

11. Post-larval Bullhead, *Cottus quadricornis*? E. E. Prince.

12. Larval Grey Gurnard, *Trigla gurnardus*, 3rd day. May 31, 1886. E. E. Prince.

13. Post-larval ditto. August 23, 1886. E. E. Prince.

14. Young ditto, side view, enlarged. August 16, 1886. E. E. Prince.

15. Young ditto, dorsal view. E. E. Prince.

Plate V.

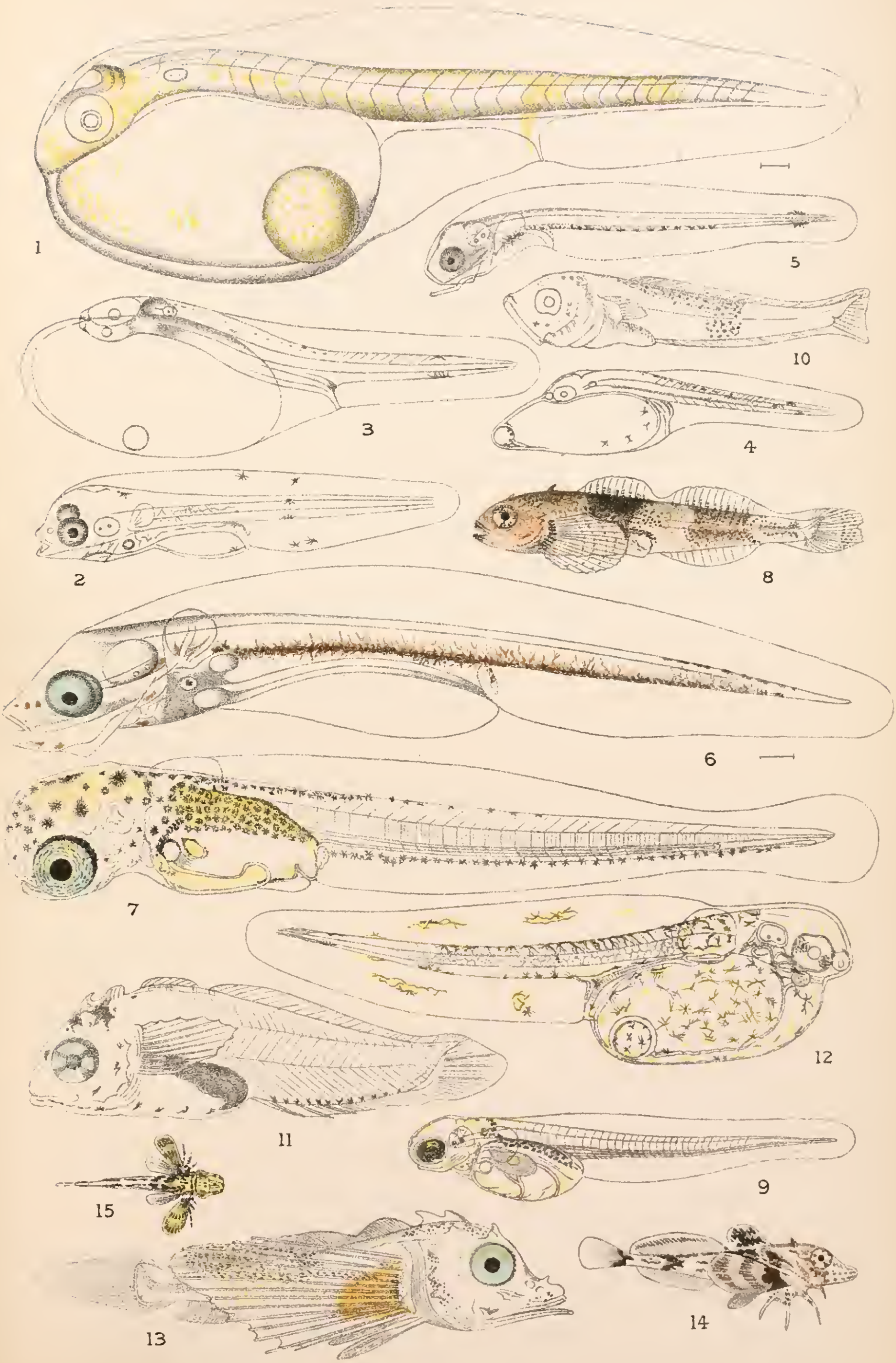

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PLATE VI.

Fig. 1. Late larval stage of Pogge, *Agonus cataphractus.* April 4, 1887. E. E. Prince.

2. Advanced post-larval ditto. April 25, 1887. E. E. Prince.

3. Newly hatched larva of Angler-fish, *Lophius piscatorius.* E. E. Prince.

4. Larva of ditto, 5th day. E. E. Prince.

5. Larva of ditto, 15th day. E. E. Prince.

6. Post-larval ditto. E. E. Prince.

7. Newly hatched larva of Lesser Weever, *Trachinus vipera.* E. W. Holt.

8. Young Lesser Weever, *Trachinus vipera*, 15 mm. long. I. M. Anderson.

9. Dorsal view of head and anterior region of male *Crystallogobius Nilssonii.* W. C. M.

10. Young male *Crystallogobius Nilssonii*, enlarged. I. M. Anderson.

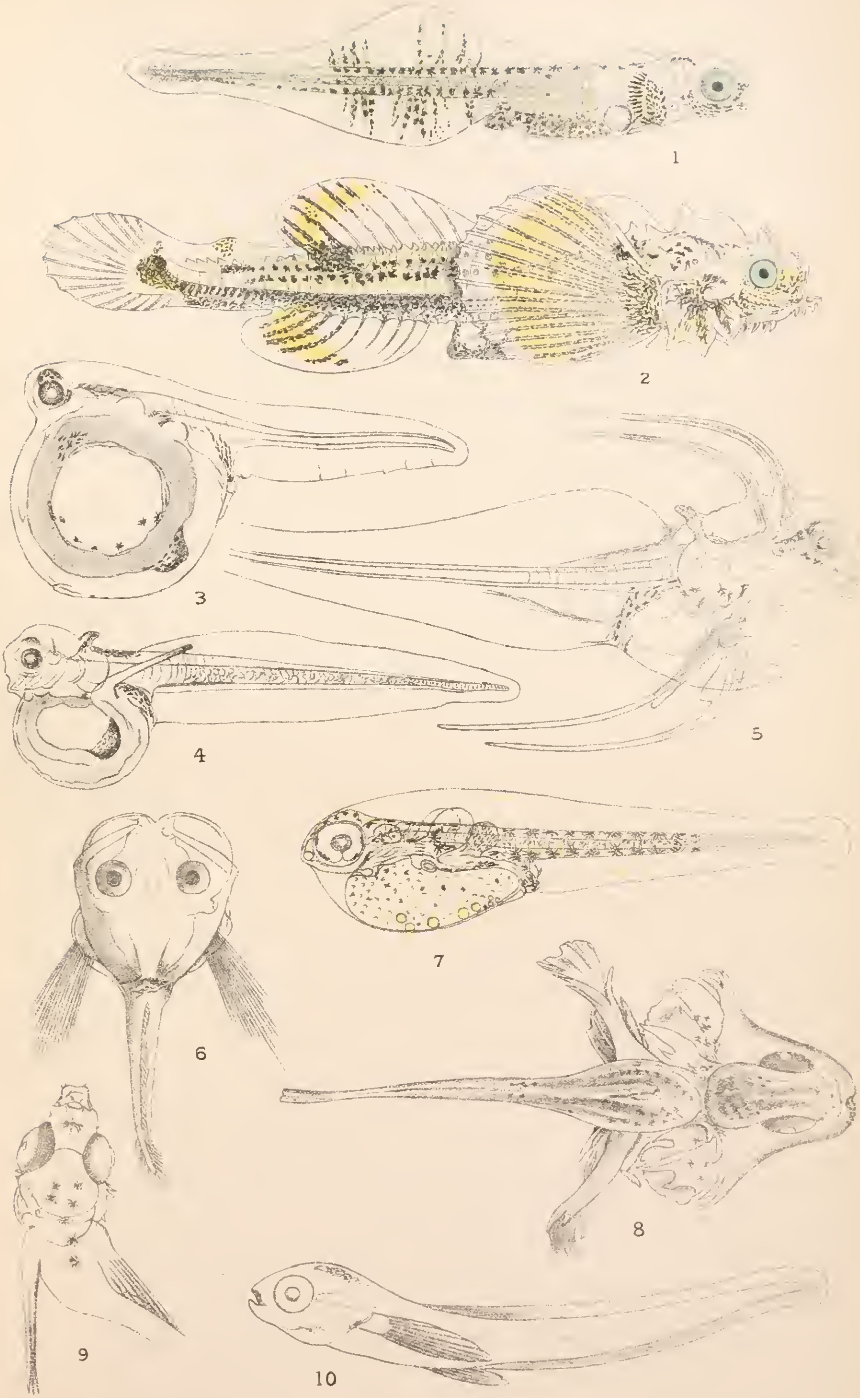

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PLATE VII.

Fig. 1. Newly hatched larva of Mackerel, *Scomber scombrus.* 1893. E. W. Holt.

2. Larval Mackerel, *S. scombrus*, about 9 days old. E. W. Holt.

3. Larval Freckled Goby, *Gobius minutus.* May 14, 1890. E. W. Holt.

4. Larval Black Goby, *Gobius niger.* C. J. Petersen.

5. Post-larval ditto. E. W. Holt.

6. Larval Dragonet, *Callionymus lyra.* E. E. Prince.

7. Post-larval ditto. August 31, 1888. J. P. Smith.

8. Young ditto, 10 mm. long. R. Scharff.

9. Advanced post-larval Montagu's Sucker, *Cyclogaster Montagui.* April 13, 1886. E. E. Prince.

10. Post-larval Lumpsucker, *Cyclopterus lumpus.* E. E. Prince.

11. Young Lumpsucker, *C. lumpus*, dorsal view. E. E. Prince.

Plate VII.

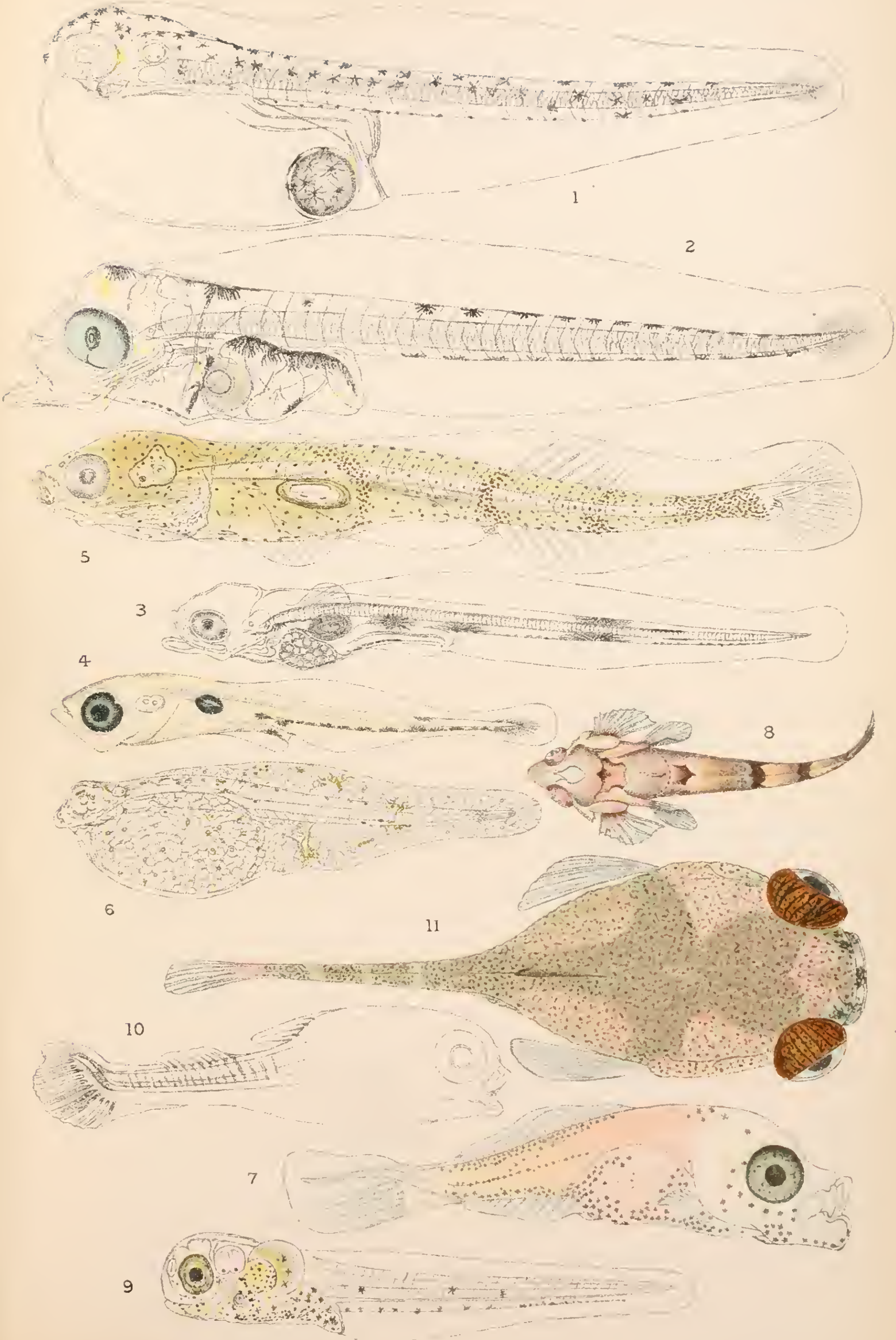

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PLATE VIII.

Fig. 1. Newly hatched larval Wolf-fish, *Anarrhichas lupus*. Jan. 28, 1886. W. C. M.

2. Young Wolf-fish, *A. lupus*. May 14, 1886. E. E. Prince.

3. Larval Bimaculated Sucker, *Lepadogaster bimaculatus*. E. W. Holt.

4. Larval Ballan Wrasse, *Labrus bergylta*. J. Duncan Matthews.

5. Larval Gunnel, *Pholis gunnellus*. W. C. M.

6. Gunnel, *P. gunnellus*, and eggs. 1893. E. W. Holt.

7. Larval Mullet, *Mugil capito*. F. Raffaele.

8. Outline of larval 15-spined Stickleback, *Gasterosteus spinachia*. E. E. Prince.

9. Post-larval ditto. E. E. Prince.

10. Ventral view of male Stickleback, *G. spinachia*, dissected to shew 'glutinous' sac. E. E. Prince.

Plate VIII.

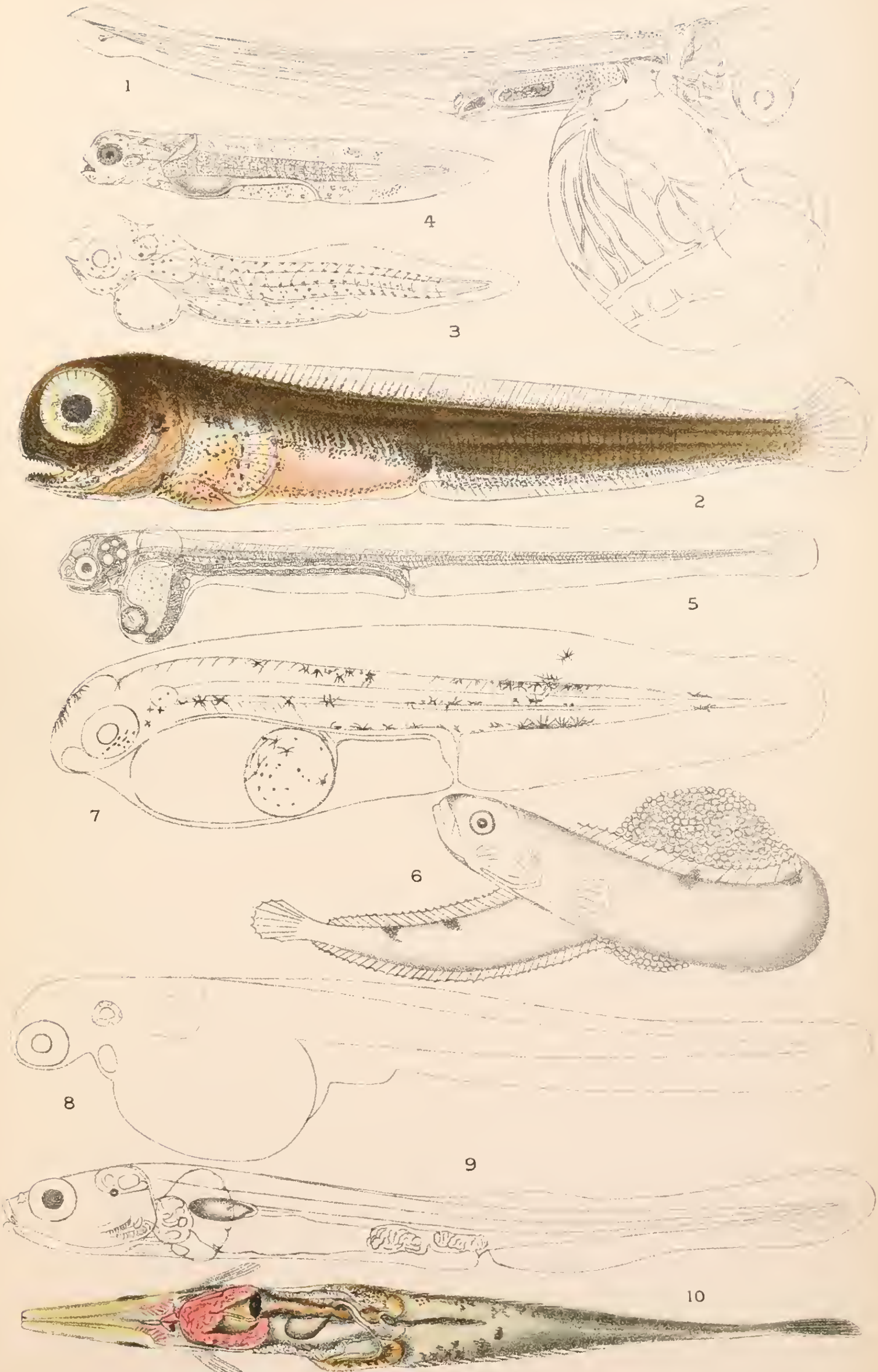

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PLATE IX.

Fig. 1. Newly hatched larval Cod, *Gadus callarius*. A. T. M.

2. Dorsal view of larvæ of ditto, 3rd day. E. E. Prince.

3. Post-larval Cod, *G. callarius*, enlarged. May 4, 1893. A. T. M.

4. Post-larval Cod, *G. callarius*, enlarged. A. T. M.

5. Post-larval Cod, *G. callarius*, enlarged. May, 1887. E. E. Prince.

6. Post-larval Cod, *G. callarius*, older stage. E. E. Prince.

7. Young Cod, *G. callarius*. June 11, 1886. E. E. Prince.

8. Newly hatched larval Haddock, *Gadus æglifinus*. A. T. M.

9. Newly hatched larval Haddock, *G. æglifinus*, ventral view. E. E. Prince.

10. Post-larval ditto, 11 days old. April 24, 1886. E. E. Prince.

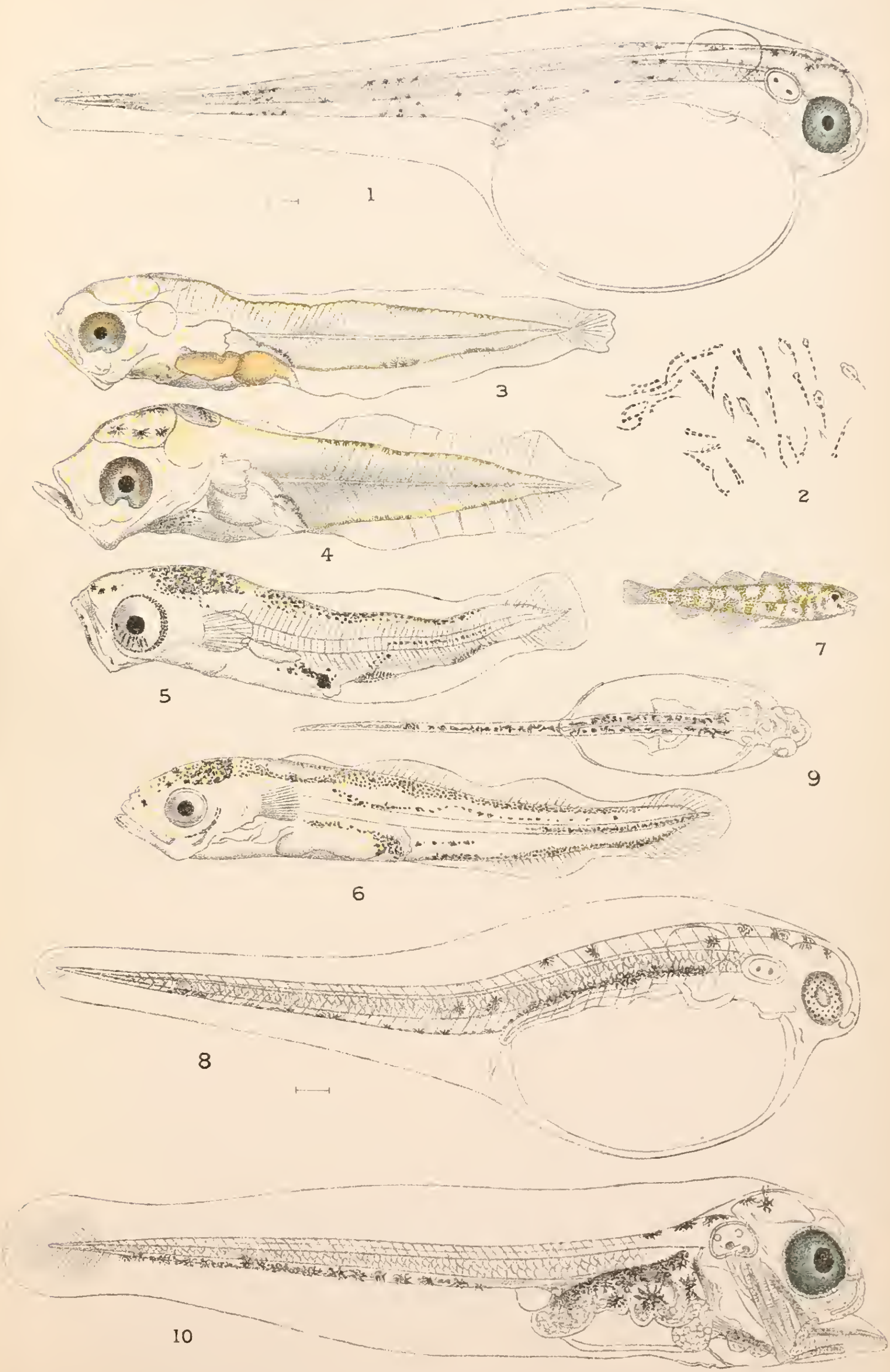

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PLATE X.

Fig. 1. Larval Poor-cod, *Gadus minutus.* June 16, 1892. W. C. M.

2. Newly hatched larval ditto. June 11, 1892. W. C. M.

3. Early post-larval ditto. June 18, 1892. W. C. M.

4. Larval Green-cod, *Gadus virens,* 2nd day. Feb. 28, 1894. W. C. M.

5. Older larval ditto. March 7, 1894. W. C. M.

6. Post-larval ditto ?, 9·25 mm. long. March 15. E. E. Prince.

7. Young ditto, enlarged. J. Pentland Smith.

8. Young ditto, dorsal view. J. Pentland Smith.

9. Larval Hake, *Merluccius vulgaris.* F. Raffaele.

Plate X

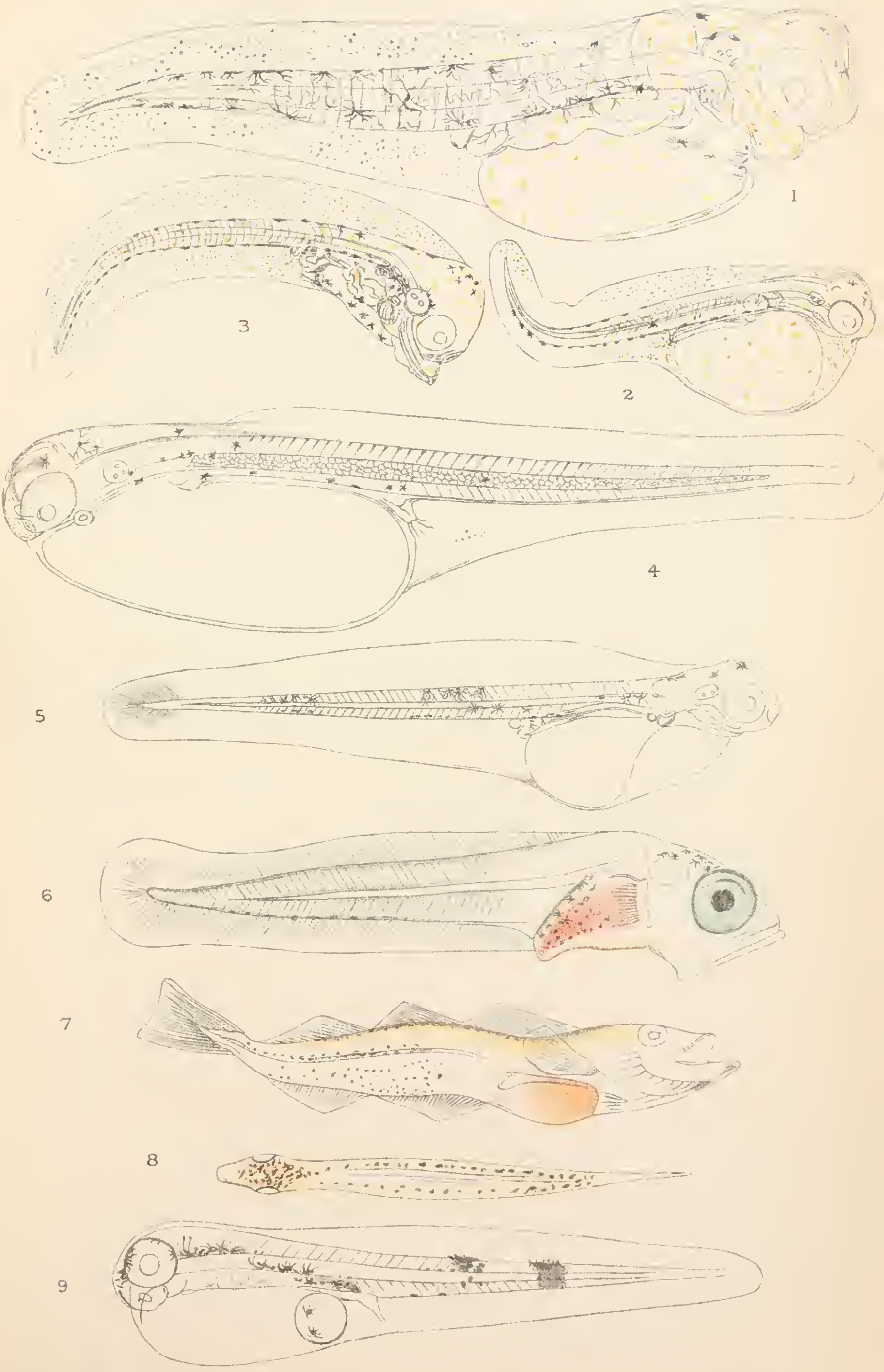

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PLATE XI.

Fig. 1. Larval Whiting, *Gadus merlangus*, 1st day. April 24, 1885. E. E. Prince.

2. Early post-larval ditto. E. E. Prince.

3. Larval Torsk, *Brosmius brosme*, 1st day. June 1, 1892. W. C. M.

4. Larval Ling, *Molua molva*, 2nd day. May 8, 1886. E. E. Prince.

5. Larval ditto, 7 days old. May 13, 1886. E. E. Prince.

6. Post-larval ditto. E. E. Prince.

7. Post-larval ditto, older stage. E. E. Prince.

8. Newly hatched larval Rockling, *Onos tricirratus* (?), placed on a slide. W. C. M.

9. Advanced larval ditto, six days old, abnormal anteriorly. May 11, 1890. W. C. M.

Plate XI

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PLATE XII.

Fig. 1. Newly hatched larval Rockling, *Onos mustela*. G. Brook.

2. Advanced larval ditto. May 11, 1890. E. E. Prince.

3. Post-larval ditto, 6 mm. E. E. Prince.

4. Post-larval ditto, older stage, 10 mm. E. E. Prince.

5. Larval Sand-eel, oblique ventral view. W. C. M.

6. Late larval Lesser Sand-eel, *Ammodytes tobianus*. E. E. Prince.

7. Post-larval ditto. A. T. M.

8. Post-larval ditto (pelagic), later stage. A. T. M.

9. Young ditto, littoral stage. A. T. M.

10. Young Halibut, *Hippoglossus vulgaris*, 32 mm., pelagic stage. C. J. Petersen.

11. Larval Long-Rough Dab, *Drepanopsetta limandoides*. April 4, 1895. W. C. M.

12. Young ditto, 11 mm. long. E. W. Holt.

13. Young ditto, 13·87 mm. long. E. W. Holt.

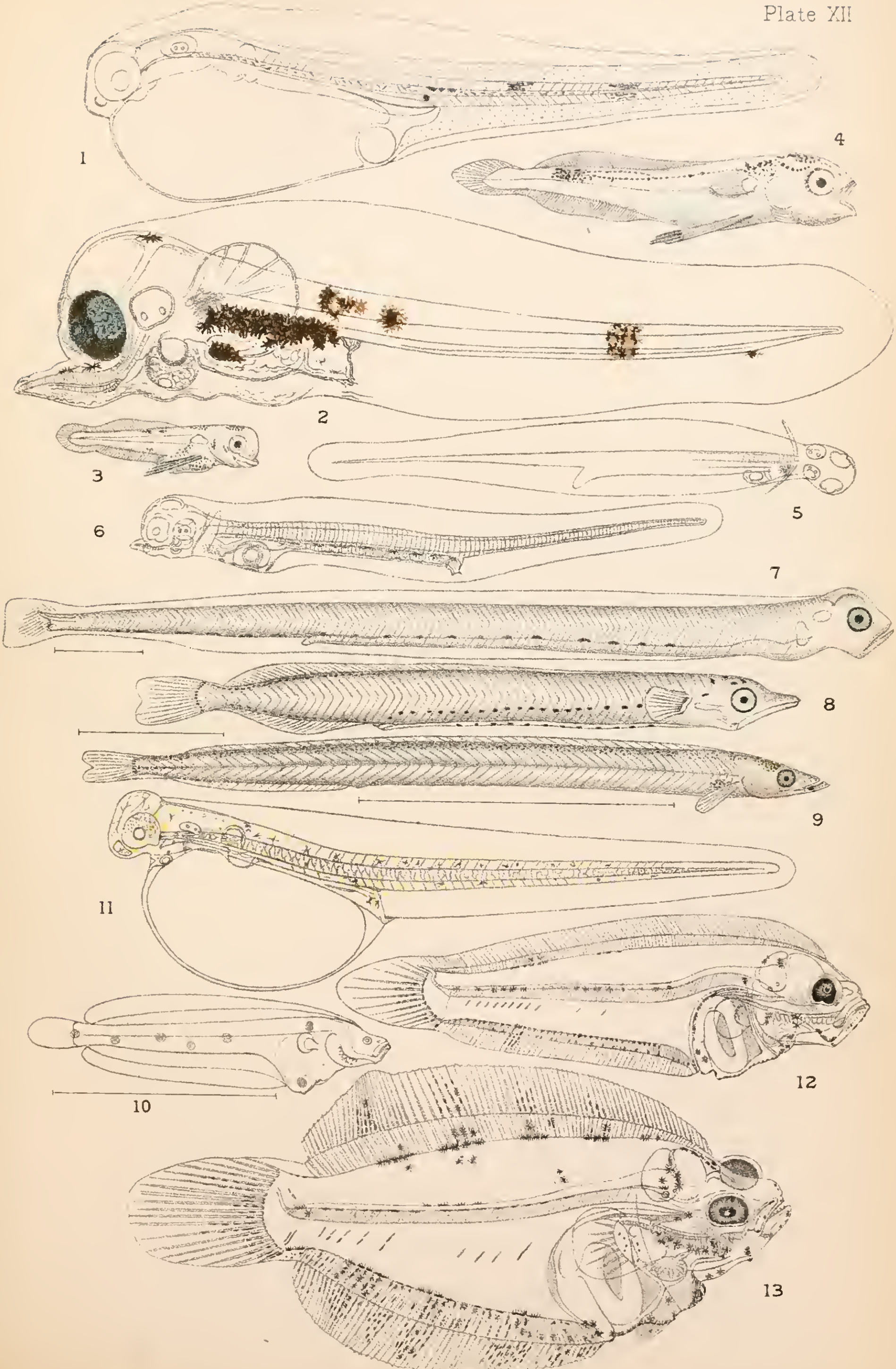

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PLATE XIII.

Fig. 1. Recently hatched larval Turbot, *Bothus maximus*. June 28, 1895. W. C. M.

2. Early post-larval ditto. July 4, 1895. W. C. M.

3. Young Turbot, pelagic stage, with spines. C. J. Petersen.

4. Young ditto, more advanced, with spines. C. J. Petersen.

5. Young ditto, somewhat older (near bottom stage). A. T. M.

6. Young ditto (bottom stage), 14 mm. long. A. T. M.

7. Newly hatched hybrid between Turbot and Brill. E. E. Prince.

8. Post-larval Brill, *Bothus rhombus*, surface. St Andrews Bay, July 11, 1890. W. C. M.

9. Post-larval ditto, 9·5 mm. long. Moray Frith, June 28, 1889. W. C. M.

10. Brill-like form, 10 mm. long. Off Aberdeen, June 23, 1893. Specimen was incomplete posteriorly. W. C. M.

11. Young Brill, without spines, pelagic. C. J. Petersen.

12. Young Brill, without spines, later. C. J. Petersen.

Plate XIII

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PLATE XIV.

Fig. 1. Newly hatched Topknot, *Zeugopterus sp.* E. E. Prince.

2. Post-larval Norwegian Topknot, *Scophthalmus norvegicus* (?), 7 mm. long. 1893. E. W. Holt.

3. Post-larval sinistral Pleuronectid, *Zeugopterus.* W. C. M.

4. Post-larval sinistral ditto, enlarged (fresh, not living). W. C. M.

5. Dorsal view of Topknot (?), with long spines over ear-capsule. July 5, 1889. W. C. M.

6. Young sinistral Pleuronectid, probably *Zeugopterus*, 5 mm. W. C. M.

7. Young sinistral ditto, 9·5 mm. W. C. M.

8. Young sinistral Pleuronectid, *Zeugopterus.* Aug. 23, 1886. E. E. Prince.

9. Young Topknot, *Zeugopterus punctatus*, nat. size. January 18, 1895. A. T. M.

10. Larval Sail-fluke or Megrim, *Lepidorhombus whiff.* June 3, 1892. W. C. M.

11. Advanced ditto. June 7, 1892. W. C. M.

12. Young ditto, 19 mm. long. E. W. Holt.

13. Young Scald-fish, *Platophrys laterna*, 25 mm. E. W. Holt.

14. Young Pole-dab, *Pleuronectes cynoglossus*, bottom stage. C. J. Petersen.

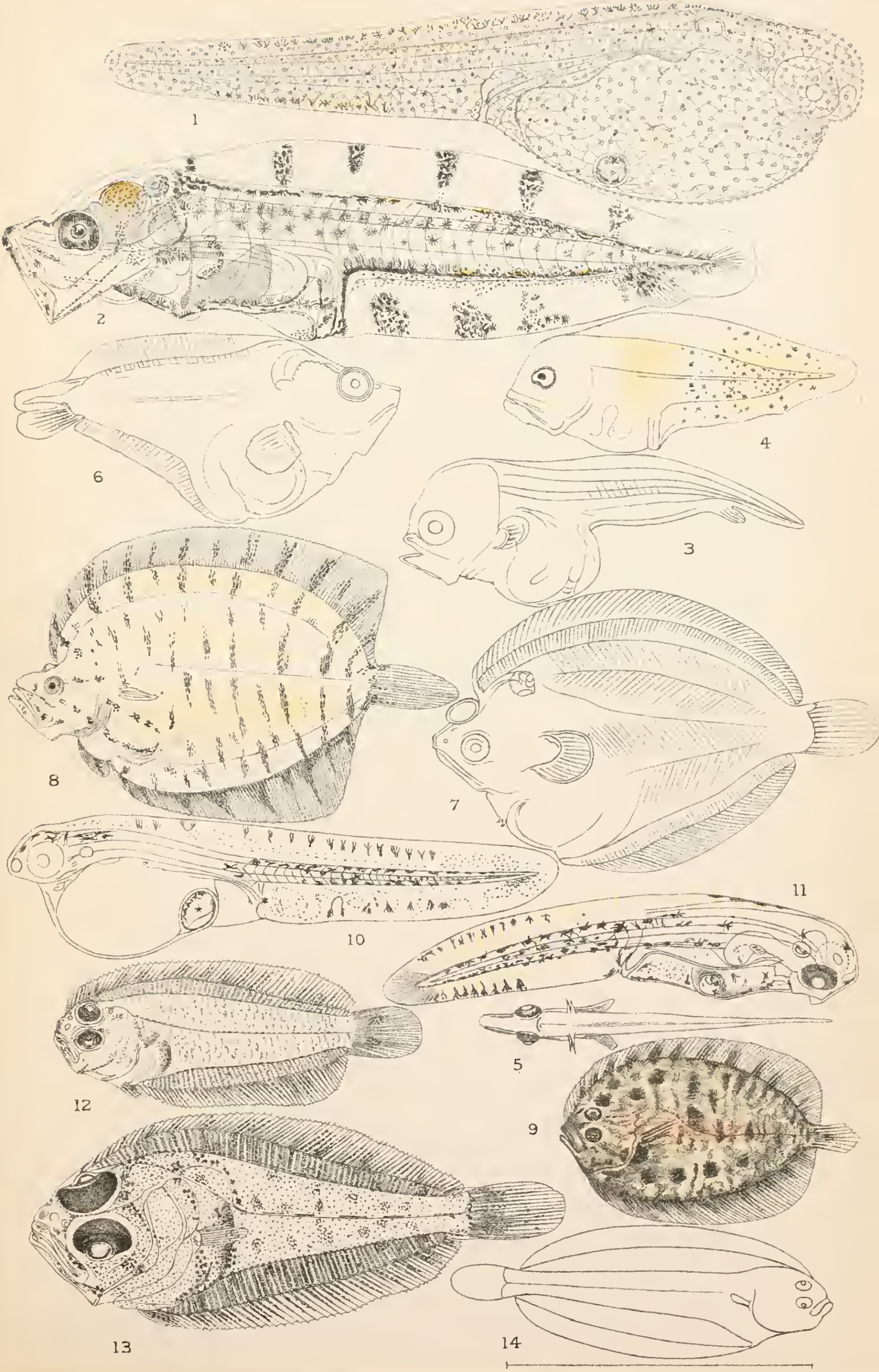

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PLATE XV.

Fig. 1. Advanced larval Plaice, *Pleuronectes platessa*. May 7, 1886. W. C. M.

2. Young (metamorphosing) ditto, 10 mm. long. E. W. Holt.

3. Young (metamorphosing) ditto, 12·8 mm. long. E. W. Holt.

4. Young ditto (bottom stage), 21 mm. long. E. W. Holt.

5. Young Plaice, bottom stage. C. J. Petersen.

6. Larval Lemon Dab, *Pleuronectes microcephalus*, 1st day. The greenish yellow has been made diffuse to save complexity in the figure. E. Teviotdale.

7. Larval ditto, ventral view. W. C. M.

8. Late ditto. W. C. M.

9. Post-larval ditto. July 4, 1893. A. T. M.

10. Post-larval ditto, 10·37 mm. E. E. Prince.

11. Post-larval ditto, pelagic stage. E. E. Prince.

12. Post-larval ditto, pelagic stage. E. E. Prince.

13. Post-larval ditto, pelagic stage. E. E. Prince.

14. Young ditto, bottom stage. W. C. M.

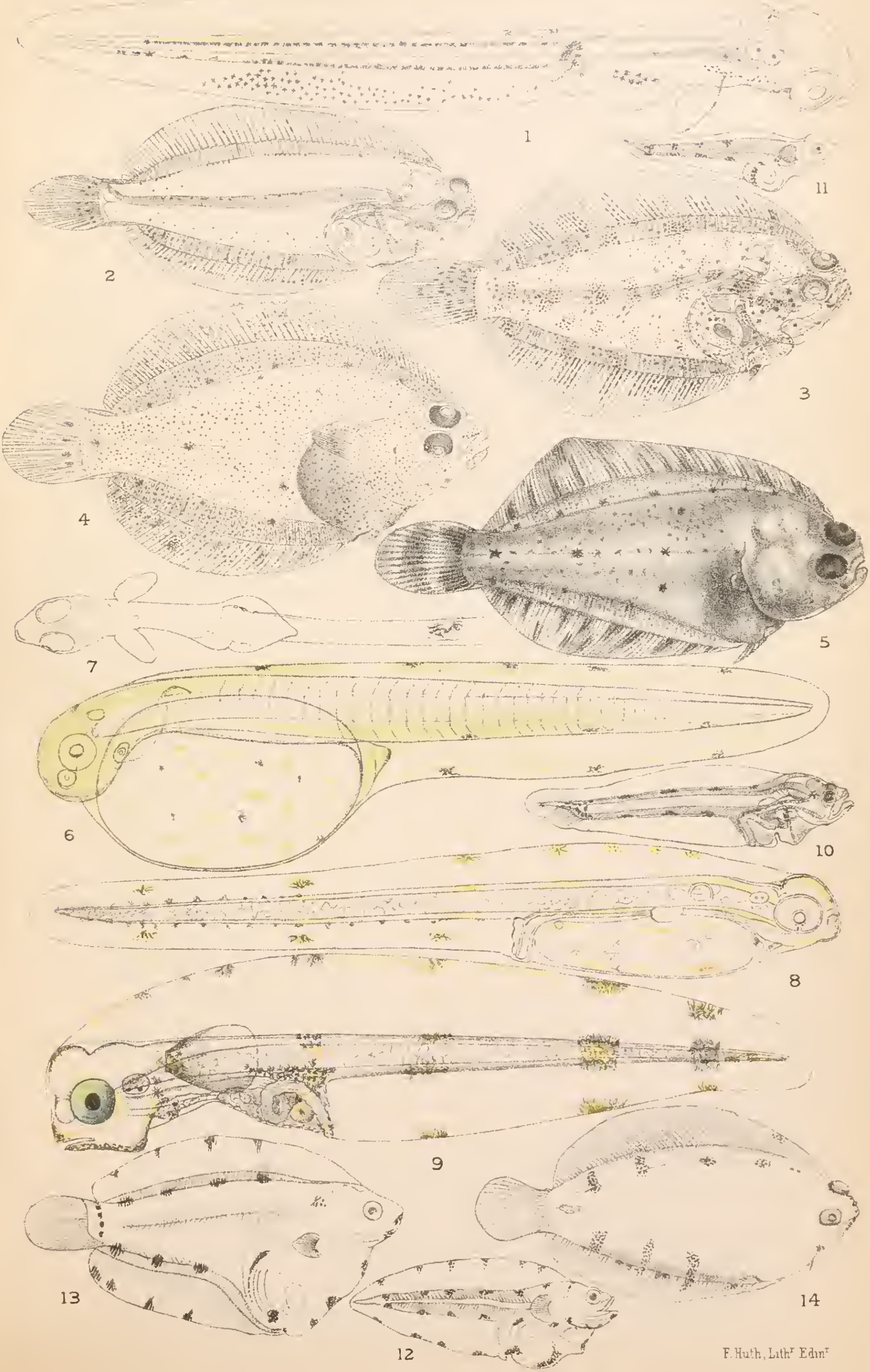

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PLATE XVI.

Fig. 1. Larva from small egg resembling that of Dab, *Pleuronectes limanda*. June 16, 1892. W. C. M.

2. Larval Pole-dab, *Pleuronectes cynoglossus*. E. W. Holt.

3. Young ditto, 42 mm., 80 fath. E. W. Holt.

4. Larval Dab, *Pleuronectes limanda*, 11 days old. May 22, 1886. E. E. Prince.

5. Post-larval Dab, *P. limanda* ?, pelagic. From a dead example. A. T. M.

6. Young Dab, *P. limanda*, 12·25 mm. long. E. W. Holt.

7. Young ditto, 15·25 mm. long. E. W. Holt.

8. Young Flounder, *Pleuronectes flesus*, bottom stage. C. J. Petersen.

9. Young ditto, later bottom stage. C. J. Petersen.

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PLATE XVII.

Fig. 1. Newly hatched larval Flounder, *Pleuronectes flesus*. E. E. Prince.

2. Larval ditto, 11 days old. April 26, 1886. E. E. Prince.

3. Post-larval ditto, pelagic. A. T. M.

4. Young ditto, bottom stage. (Two earlier stages are shown on Plate XVI.) C. J. Petersen.

5. Young ditto, showing the tissues viewed by transmitted light. E. E. Prince.

6. Young ditto }
7. Young ditto } showing the successive changes in pigmentation during confinement. E. E. Prince.
8. Young ditto }

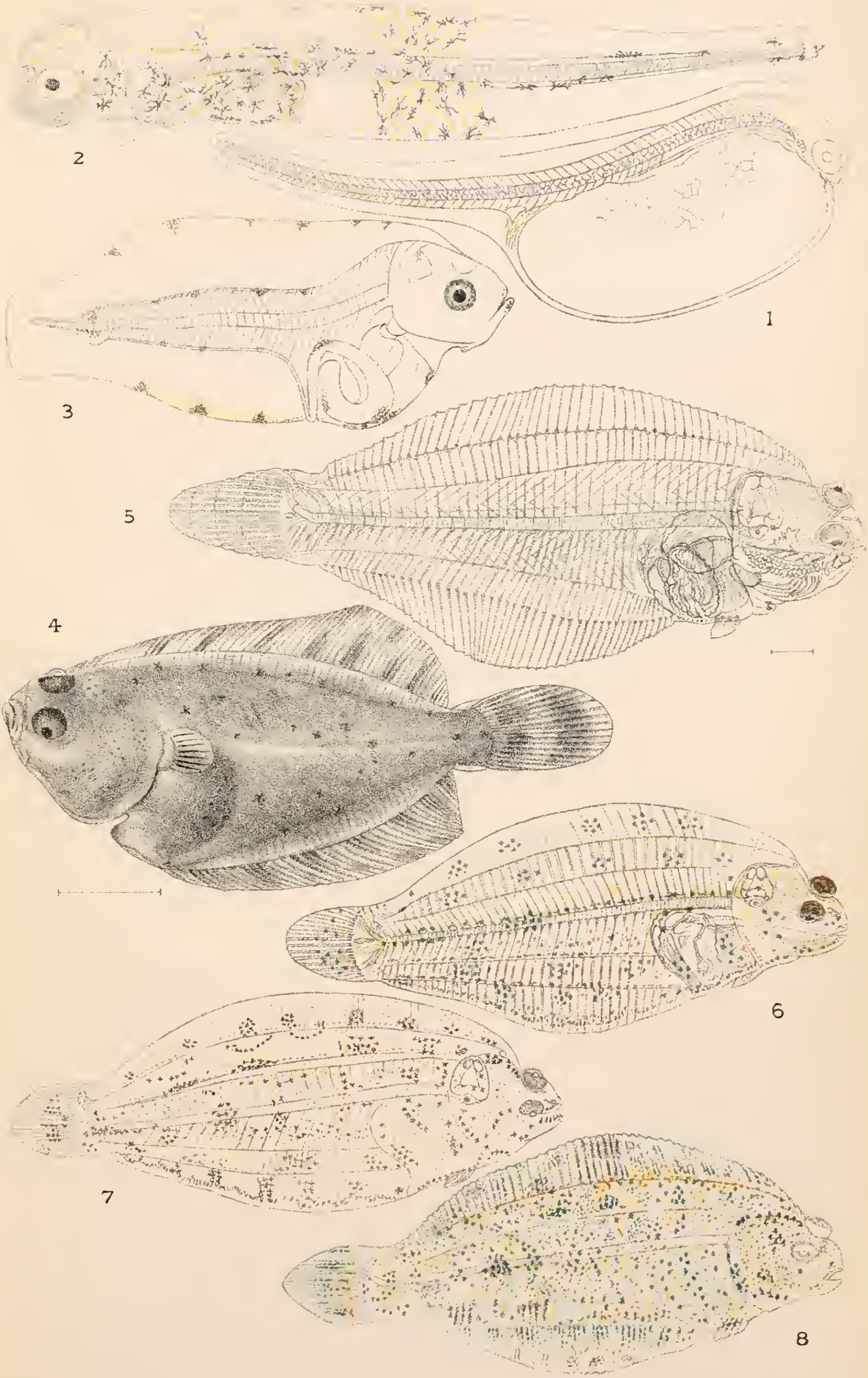

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PLATE XVIII.

Fig. 1. Larval Solenette, *Solea lutea.* July 12, 1895. J. R. Tosh.

2. Newly hatched larval Sole, *Solea vulgaris.* E. E. Prince.

3. Post-larval ditto. J. P. Smith.

4. Newly hatched larval Sprat, *Clupea sprattus.* W. C. M.

5. Later larval ditto. W. C. M.

6. Newly hatched larval Anchovy. F. Raffaele.

7. Later larval ditto. F. Raffaele.

8. Early post-larval ditto. F. Raffaele.

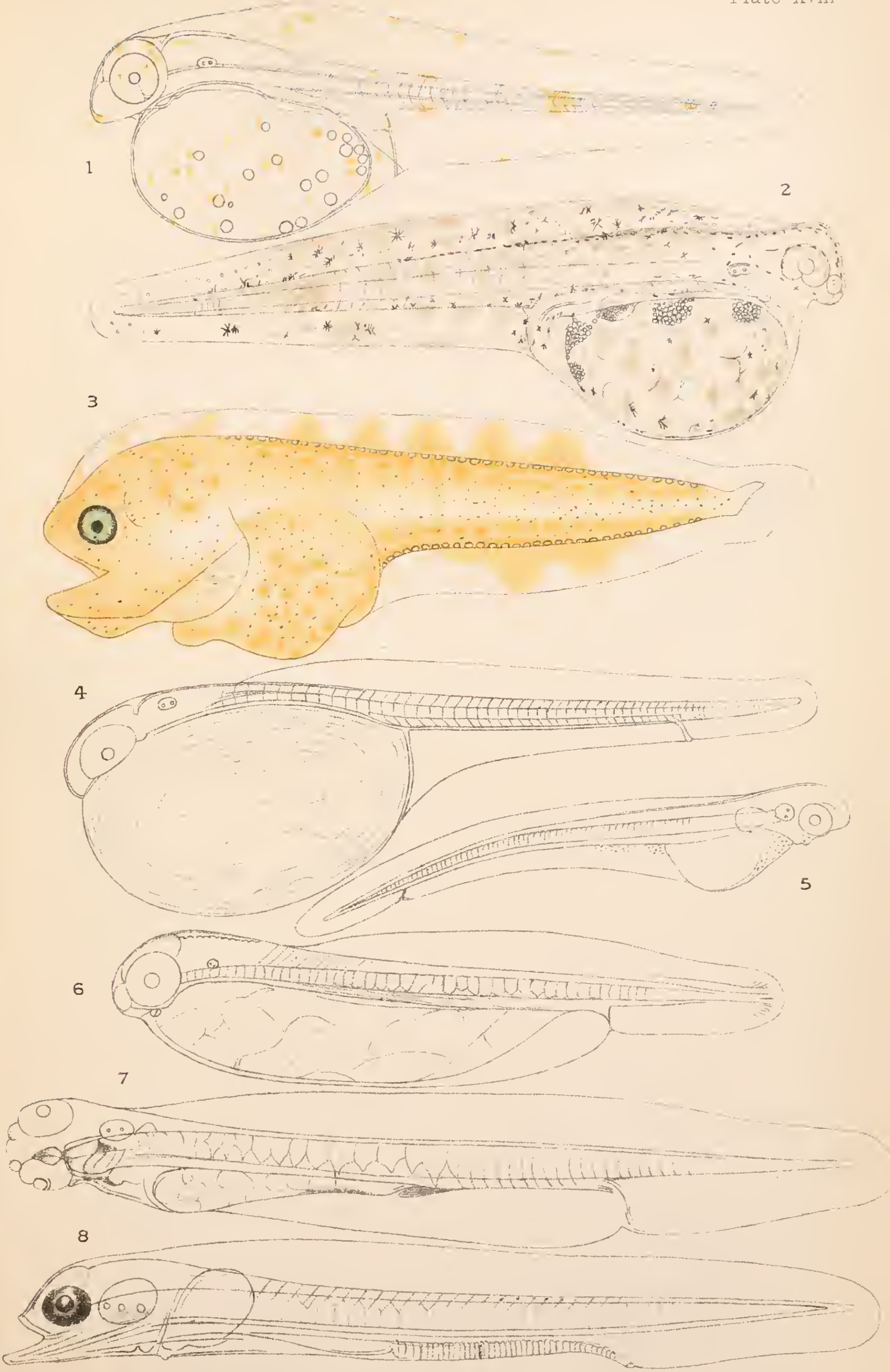

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PLATE XIX.

Fig. 1. Newly hatched larval Pilchard, *Clupea pilchardus*. F. Raffaele.

2. Larval Herring, *Clupea harengus*, bottom stage. A. T. M.

3. Late larval ditto, bottom stage. A. T. M.

4. Post-larval ditto, mid-water and surface-stage. A. T. M.

5. Young ditto, littoral stage. A. T. M.

6. Young Conger, *Leptocephalus morrisii*. 1869, St Andrews. A. T. M.

7. Early post-larval Sprat, 4·7 mm. 15th July. E. Ehrenbaum.

8. Later post-larval ditto, 18·5 mm. 18th July. E. Ehrenbaum.

9. View of the anterior end of murænoid (?), species no. 6, Raffaele, 4 days after hatching. Naples. H. C. Williamson.

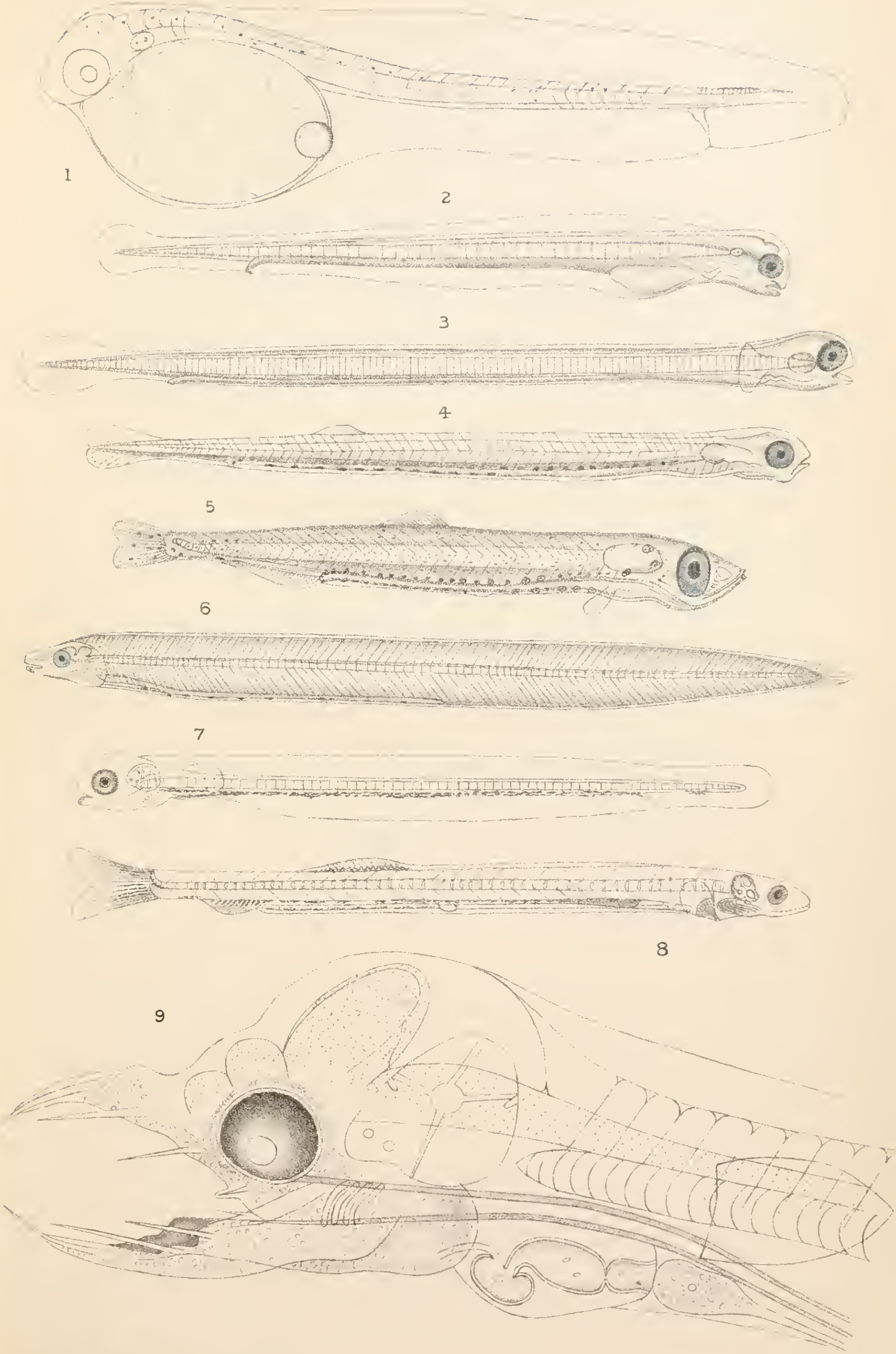

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PLATE XX.

Fig. 1. Newly hatched larval Brill. E. Ehrenbaum.

2. Newly hatched Scald-fish, *Platophrys laterna*, 2·57 mm. 10 July. E. Ehrenbaum.

3. Symmetrical pelagic stage of ditto, with long dorsal filament. 4·7 mm. long. 14 Sept. E. Ehrenbaum.

4. Early post-larval Solenette, 3·67 mm. 12 July. E. Ehrenbaum.

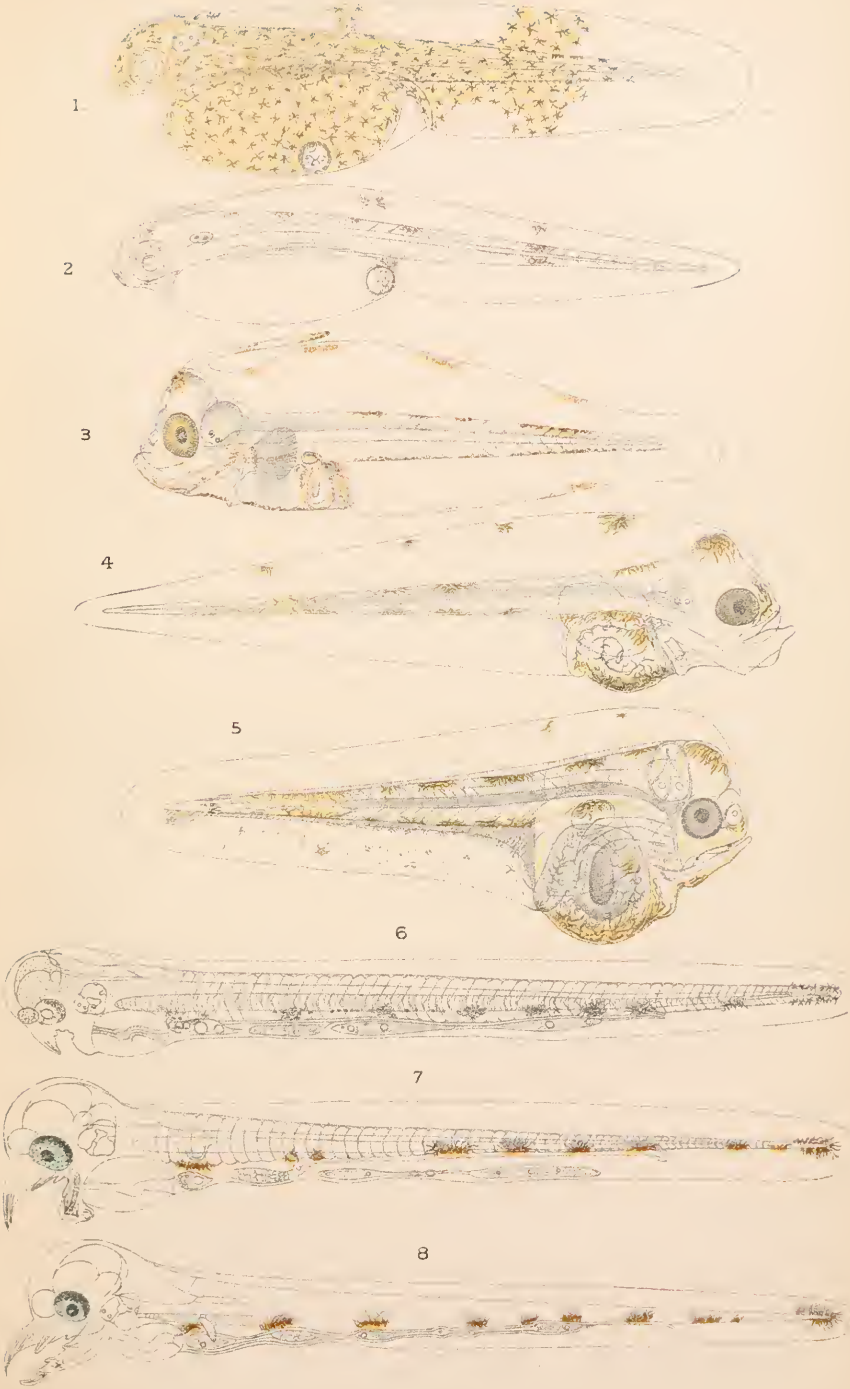
5. Symmetrical post-larval ditto, 6·3 mm. long. 16 July. E. Ehrenbaum.

6. Muraenoid (?) species no. 8, Raffaele, 2 days old. Naples, 26 Aug., 1895. H. C. Williamson.

7. The same larva a day older, showing the shovel-shaped lower jaw with the developing teeth. Naples. H. C. Williamson.

8. A larva which hatched about the same time as fig. 6, a day older than the preceding (fig. 7). H. C. Williamson.

Plate XX



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