THE

NATURAL HISTORY

OF THE

MARKETABLE MARINE FISHES

OF THE

BRITISH ISLANDS

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PREPARED BY ORDER OF THE COUNCIL OF THE MARINE BIOLOGICAL ASSOCIATION ESPECIALLY FOR THE USE OF THOSE INTERESTED IN THE SEA-FISHING INDUSTRIES

BY

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WITH A PREFACE BY

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London

MACMILLAN AND CO., Ltd.

NEW YORK: THE MACMILLAN CO.

1896

Richard Clay and Sons, Limited,
london and bungay

PREFACE

THE work which, as President of the Marine Biological Association, I have the pleasure of introducing to the public with a few lines of preface, has been prepared at the request of the Council of the Association by Mr. J. T. Cunningham. The author has for several years occupied the position of naturalist at the Plymouth laboratory, being especially charged by the Council with the investigation of the structure, habits, and breeding of marine food-fishes. He had previously given a large amount of study to this subject whilst in charge of the marine laboratory at Granton near Edinburgh. Since many of Mr. Cunningham's important observations on the "growth from the egg" of marine fishes have been published in the strictly scientific journals and transactions of societies, it seemed to be desirable that the results of the recent study of the reproduction of the fishes which form the material of our sea-fisheries, should be brought together in a convenient and popular form. The marked increase of attention to the natural history of these fishes which is traceable to the great Fisheries Exhibition held in London in 1883, has led to a large increase of knowledge. On various parts of our coasts, naturalists have been busy in the endeavour to arrive at an accurate estimate of the causes which determine the movements and the variations in abundance of the animals which produce the "harvest of the sea." An immense amount of work remains to be done before we shall be in a position to control the operations of fishermen or to assist them by advice or forecasts in a satisfactory manner. At the same time a good deal has been done, and the work is one in which amateurs all round our shores can assist. Mr. Cunningham's book will, it is hoped, serve as a help not only to trained investigators but to those who are able to give some portion of their leisure to this important subject. It is hoped also that it may help those who are responsible for giving or withholding public funds to the thorough investigation of marine fisheries, in forming a judgment as to the nature of the problems which have to be solved. The national importance of the sea-fisheries industry is recognized by the legislature. But the right way of developing and directing that industry, and indeed whether it is possible to do anything to improve that industry, are questions which seem still to be matters of doubt to all but the professed students of marine life and its conditions. This book, together with the several volumes of the journal of the Marine Biological Association and the finely illustrated monograph by Mr. Cunningham on the common sole, may be taken as setting forth the results of the work done by the Marine Biological Association in the direction of contributing to a better knowledge of sea-fishes and sea-fisheries. That work has been done to a large extent by the aid of grants from Her Majesty's Treasury, with which the Association has been entrusted by the Government. The line of work pursued has been necessarily limited by the funds at the disposal of the Council of the Association. The results obtained are undoubtedly valuable; at the same time I cannot let this opportunity pass of stating that a larger and much more costly series of investigations is necessary, and that nothing short of a physical and biological survey of the North Sea and of the area within the hundred-fathom line on our southern and western coasts can yield the information as to the movements of marine food-fishes and the distribution of fishing-grounds which is needful if we are to deal intelligently with our sea-fisheries. This and the collection (even though costly) of statistical information as to the capture of fish on specified fishing-grounds, which at the present moment is entirely neglected though practicable, are the two requirements of those who desire to improve, and preserve by intelligent action, our fishing industry. I believe that Mr. Cunningham's book will place the reader in a position to appreciate the importance of these requirements.

The purpose of the Association under the auspices of which Mr. Cunningham has worked, was stated, on its foundation, in the words of Professor Huxley, its first President, to be that of "establishing and maintaining laboratories on the coast of the United Kingdom, where accurate researches may be carried on leading to the improvement of zoological and botanical science, and to an increase of our knowledge as regards the food, life-conditions, and habits of British food-fishes and molluscs." The Association was founded in 1884 and the Plymouth laboratory was opened in 1888, having cost in building and fittings about £12,000. The studies of the naturalists, who are officers of the Association, have not been confined to the neighbourhood of Plymouth, but have included some investigation of the North Sea fisheries, in the course of which the marine laboratory at Cleethorpes was lent to the Association by the Society to which it belongs. Those who read Mr. Cunningham's account of our marine food-fishes and feel an interest in the subject of which he treats, and in the enterprise of the Marine Biological Association, will be able to obtain all information as to the Association, its laboratory, its publications, and the terms of membership by applying to the Director of the Marine Biological Laboratory, Citadel Hill, Plymouth. It would not perhaps be in good taste to discourse at greater length in this preface concerning the Association and its laboratory. I will, however, venture so far as to state that in addition to promoting and publishing works directly relating to sea fisheries, the Association has through its laboratory and fishing boats at Plymouth furnished a large number of naturalists who have occupied tables there, with the means of prosecuting minute researches of great scientific value on the marine fauna and flora. It is also the means of providing

University and College teachers with large supplies of marine organisms for teaching purposes and special investigations. Its aims are national in their importance and not merely local ; it requires and invites the co-operation of all those who are interested in the study of marine life, or in the perilous labours of the sea fisherman.

Before concluding this preface I must express the thanks of the Council of the Marine Biological Association to the Council of the Royal College of Surgeons of England, and the Hunterian Curator, Professor Stewart, F.R.S., for kindly allowing Mr. Cunningham to make use of a room in their Museum during the past year whilst engaged in preparing this book for the press, and in pursuing his researches on the structure of the ovary of marine food-fishes.

E. RAY LANKESTER.

October, 1896.

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CHAPTER I

HISTORY OF MODERN INVESTIGATIONS OF THE SUBJECT

OUR knowledge of the natural history of the majority of our most valuable marine food-fishes is of quite recent growth, and, although now there is a good deal of it, much more is still required. When I write *our* knowledge, I mean that which has been obtained and published, for the number of those who have made that knowledge their own is small indeed. Those to whom the study of nature is a familiar pleasure, or the regular work of life, are not a large class. On the other hand, those who handle fish continually in the course of their daily business, whether in the boat or in the market, have, for the most part, not yet realised that any knowledge concerning fish which they do not possess can be of any value. It can scarcely be expected that the fisherman or fish merchant will spend his short and hard-earned leisure moments in the study of the blue books and technical memoirs in which the results of research are described ; and when certain newly-established facts are brought before them in other ways, it frequently happens that they either deny these facts as contrary to their own experience, or turn a deaf ear from the conviction that such matters are of no practical importance. With reference to the contradiction of the naturalist's conclusions, it may be urged that, although he may not be able to climb the rigging of a smack, and is generally sick while at sea, although also he may be as ignorant as a baby of the mysterious and complicated practice of the fish trade, still he has two advantages over the professional fish-man in attempting to get at the truth concerning the life and habits of fish. Firstly, he has been trained to appreciate the value of scientific evidence, and is on his guard against jumping at conclusions; secondly, he can use instruments of precision, which are as essential to the investigation of some of the matters in question as the compass and the lead to the handling of a fishing vessel. With regard to the practical importance of the naturalist's researches and results to the fishing industry, it can only be said that there is no doubt about it. It is an undeniable fact that Parliamentary legislation and local bye-laws are at the present time constantly being demanded or proposed for the benefit of the fisheries, and the reasons by which these proposals and demands are supported consist largely of statements concerning the natural history of the fishes and other marine creatures concerned. It is necessary, therefore, that we should be able to test the correctness of these statements, and should be able to judge correctly of the most probable effect of the measures proposed on the productiveness of the fisheries.

Before the year 1862 very little attention had been given by experienced naturalists to the natural history of sea-fishes, particularly of those valuable in the market. There are, it is true, numerous important books of older date in which fishes are described, such as those of Yarrell and Couch, giving an inclusive account of British and Irish fishes. But the information in these works concerning the habits and history of the fish is scanty and not always correct. An important advance in our knowledge of the herring was made in 1862, when Mr. Allman, then Professor of Natural History in the University of Edinburgh, at the request of the Scottish Fishery Board, made a systematic investigation of the spawning of herring in the Firth of Forth. The principal results of this inquiry are recorded in the Report of the Royal Commission on the Operation of the Acts relating to Trawling for Herrings on the coasts of Scotland, which Report was published in 1863. Professor Allman dredged up the spawn of the herring from rough rocky ground near the Isle of May at depths of 14½ to 20 fathoms. The eggs were firmly glued to stones, shingle, empty shells and coarse sand, and were found even on the backs of small living crabs. The Report just mentioned contains a summary of all that the Commissioners, two of whom were Dr. Lyon Playfair and Mr. T. H. Huxley, could discover concerning the natural history of the herring, but their conclusions were almost entirely founded on the evidence afforded by the assertions of others, evidence in the ordinary legal sense, not on circumstantial evidence examined by themselves at first hand. Professor Allman's observations, however, have been confirmed and extended since that time, and he was the first to establish the fact that the spawn of the herring, like that of many shore fishes and fresh-water fishes, adheres to solid objects in the water.

But one of the fundamental and most important facts concerning the mode of life of sea fishes is that the spawn of a great many of them is buoyant, and floats about invisible in the waters of the sea. The story of the discovery of such spawn was written by the discoverer himself in a very interesting manner. But it was written in the Norwegian language, and is only available for English readers in the translation provided by the United States Commissioner of Fish and Fisheries, in one of his bulky annual reports, that for 1877. In the year 1864 and some following years, the Norwegian Government commissioned Mr. G. O. Sars, a qualified naturalist of the Christiania University, to carry out an examination of the cod-fisheries of the Lofoten Islands, and of the natural history of the cod. In his report Mr. Sars says that he had in former times heard from fishermen that the roe of the cod could be seen floating in the water, and that it was sometimes so abundant as to make the water thick. But he knew that the eggs of many fresh-water fishes and of sea fishes found near the shore were attached to stones or weeds, and he knew that many kinds of lower aquatic animals swarm in the surface waters of the sea. He supposed, therefore, that this opinion of the fishermen was a mistake. However, when he investigated the matter off the coast of the Lofoten Islands, he found that the fishermen were perfectly right. The use of a small, fine net towed through the water from a vessel is necessary for the collection of all the more minute living things which swarm in the waters of the sea, and which, making up by their vast numbers for their small size, play such an important part in the great drama of marine life. The principle of the net is very simple. It may be made of cheap muslin or expensive silk bolting cloth, but all that is required is a bag of any size made of cloth of such texture that the water can pass through it, and kept open at the mouth by a hoop of iron, brass, or wood. When the net is hauled in, turned inside out, and its contents washed into a jar of clean sea-water, living things of an extraordinary variety and abundance are found. Among the material collected by such a net Sars found a number of small, completely transparent globules, which the microscope showed to be eggs of some kind. These eggs became daily more abundant, until about the end of March they were more numerous than any other kind of thing in the sea-water. He was able to trace their development, and found that a tender little fish was produced in them, and at last hatched. He satisfied himself that these clear globules were really the spawn of the cod in the following way:—Numbers of cod were caught which were full of roe, and ripe, so that a little pressure caused the spawn to run out. He put this spawn into clean sea-water. To quote his own words, "This roe did not sink to the bottom, but floated on the water like that which I had first observed. This peculiarity of the roe of the cod-fish, to which no parallel is found in any other fish, must be caused partly by the absence of the gluey matter which in nearly all other fish holds the eggs together, partly by an unusually large quantity of fine oil contained in the egg, which makes the specific weight of the roe a little less than that of the water. Only when the fœtus is dead, and the egg shrinks in consequence, does the roe sink to the bottom; unless this is the case, it continues to float in the water during the whole period of its development; and even the young fish recently hatched floats about in a similar manner, with its umbilical bag attached to it, which for some time supplies it with food." There was no difference at all between the spawn taken from the fish and that obtained from the sea. It appears from Sars' report that in this first year he did not carry out artificial fertilisation, but contented himself with comparing the eggs in the sea with the unfertilised eggs obtained from the female fish. The next year (1865) he continued his studies. He kept numbers of the eggs in glass jars of sea-water till they were hatched, and then kept the fry alive for more than two weeks. The cod were very abundant this year, and in one region on a calm day he found the sea covered with a thick layer of the floating spawn. Sars took some ripe eggs from the fish and put some milt into the water containing them, and found they were impregnated. The outline of the embryo was seen in the eggs eight days after the fertilisation, and in eighteen days the tender little fish were hatched.

The Norwegian naturalist considered that in consequence of the condition of this floating spawn enormous quantities of it were destroyed by the waves, or washed ashore, or driven to distant places by the currents and the wind. He suggests, therefore, that it might be worth while to direct large quantities of the spawn to places where it would be safe from the wind and waves.

When he first became acquainted with it, Sars, as we have seen, thought that the spawn of the cod was exceptional and unique in its buoyant character. He soon found, however, that this was by no means the case. He first found that the spawn of the haddock was quite similar to that of the cod, and he also saw three other kinds of floating spawn among the material collected by his surface-net. In the summer of 1865 he visited the centre of the mackerel fishery on the south coast of Norway, and found that the eggs of the mackerel were also lighter than sea-water, and floated about in the sea during their development. In subsequent years the attention of Sars was given to the later periods of the history of certain fishes, and to the general zoology of the sea: he did not extend his investigations of the mode of spawning much more widely. But the subject was taken up by other observers. In 1868, Malm, a Swedish professor, of Göteborg, obtained and artificially fertilised the eggs of the common flounder. The object he had in view was rather to see the earliest stages of development, than to make out the conditions under which the spawn is naturally shed and developed. But in his published account he stated that the eggs were small, transparent, and globular, separate and free in the water. He does not state that they floated, but remarks that when disturbed they remained suspended in the water a long time. These observations were made on the coast of one of the islands off Göteborg, and, therefore, it will be noted the spawning flounders were taken in the sea, not in an estuary or a river.

For some years after this no important additions were made in Europe to the number of fishes known to produce buoyant spawn, but in the United States of America Professor Alexander

Agassiz devoted special attention to the subject, collecting the floating eggs and young stages of fishes at Newport. But it was not till 1882 that he published an account of these observations. He then stated that he knew from personal observation that the eggs of the majority of kinds of American flat-fishes, and many other fishes, floated in the water. In Europe the fact that the eggs of flat-fishes are of the buoyant kind was confirmed by a German naturalist, Victor Hensen, who traced the eggs of the plaice and flounder in the neighbourhood of Kiel, in the Baltic, in 1882.

The study of floating spawn in this country commenced in that part of it called Scotland in the year 1884. In that year Professor McIntosh was carrying on observations for the information of the Royal Commission on beam trawling, and I myself was working independently at Granton, near Edinburgh. Professor McIntosh observed the floating of the ripe, healthy eggs of a large number of fishes, including the cod, haddock, whiting, grey gurnard, common flounder, turbot, common sole, and lemon sole, more correctly to be called lemon dab. The present writer in 1885 and 1886 published figures and descriptions of the floating eggs of cod, haddock, and whiting, and of the plaice, flounder, dab and witch. Since that time more detailed knowledge has been obtained. But in referring to the year 1884, it is interesting to turn to the Report of the Commission above mentioned, issued in 1885, and read how confident and universal were the assertions made by the professional witnesses as to the destruction of fish spawn on the sea bottom by the beam-trawl. Even as recently as 1893, one of the witnesses most experienced in the fishing industry told the Select Committee on Sea Fisheries that, in his opinion, plaice spawn sank, and only after it had matured to a certain point began to lift from the bottom.

The investigation of problems relating to the fisheries is not of a kind to attract voluntary private effort. It does not promise great individual rewards in the shape of either fame or fortune, nor are the researches of that abstract philosophical kind which, like virtue, are their own reward, and are therefore pursued for their own sake with no ulterior object. The investigations of Professor Allman and Professor Sars, which have been mentioned, were undertaken at the instance of public authorities. But these were special researches involving only temporary activity by a single naturalist. Subsequently the necessity for co-operative and continued inquiry was generally recognised, and permanent institutions for the purpose were organised and supplied with funds from public revenues. This happened first in foreign countries, where governments are usually more ready to take action in such matters than in our own.

The United States Commission of Fish and Fisheries was started in 1871. It owed its existence to the knowledge, enthusiasm, and influence of Mr. Spencer Baird, the Secretary of the Smithsonian Institution, who was appointed Commissioner without salary. The first Report was published in 1873, and consisted of evidence concerning the decrease in value of the New England fisheries, with papers on the history of certain of the more valuable fishes. The second Report, dated 1874, describes the commencement of the shad-hatching operations, which have since taken such a large development.

The Reports have been issued annually up to the present time, and in addition a Bulletin is also now published in separate papers. The two series contain a vast amount of information concerning the history of American fishes, and all matters connected with American fisheries. The Commission has further taken part with other public institutions in the United States in the preparation and publication of a series of quarto volumes containing a systematic and detailed description of the valuable aquatic animals and fishing industries of the United States. In relation to our own sea-fishes and sea-fisheries the results of the American investigations are often instructive, particularly with regard to the kinds of fishes which exist on both sides of the Atlantic. Many British and European kinds, however, are absent from the American side, and therefore the American literature does not supply so much material for the summary which is given in the present work, as British and European publications.

In 1870 was instituted by the Prussian Minister of Agricultural Affairs the Commission for the Investigation of the German Seas, which has its headquarters at Kiel. This consisted of a small number of professors of Natural History, who were supplied with funds for the expenses of organised researches. They began by making voyages of investigation in the Baltic and the North Sea, and in 1874 to 1876 carried out some most searching and fruitful investigations into the history, habits, and breeding of the herring. The several branches of the research were taken up by different investigators—one studied the breeding grounds, and the conditions of the development and growth; another, the development of the egg from the microscopical point of view; another, the question of the varieties of the herring. The results were published in complete and fully illustrated memoirs, and these form the richest store of knowledge concerning the herring which is up to the present time in existence. In more recent years the Reports have dealt with various matters connected with the science of the sea, but have not had so direct a bearing on the history of particular food-fishes.

In the years between 1870 and 1880, little or nothing was done in this country towards the elucidation of the history of sea-fishes. The amount of knowledge of the subject which was available at the end of this period, and just before the commencement of the systematic and special investigations which have been carried on in recent years, can be ascertained by the examination of three general summaries which were published at that time, and of which a brief review may be here given.

In the year 1878 the celebrated Frank Buckland and Mr. Spencer Walpole, at the time Inspectors of Fisheries for England and Wales, under the Home Office, were specially commissioned by the Home Secretary to make inquiries into questions relating to the fisheries. They published a Report in 1879 which, in consequence of the fact that one of the Commissioners had long made a special study of the subject in question, is of greater value than the majority of blue books. In this Report Mr. Buckland gives in two Appendices a summary of all that was known at the time, so far as he could discover, concerning the lives and habits of our commercially valuable sea-fishes. In the Report the following statements are found:—

"The greatest ignorance prevails about the habits of sea-fish. Speaking generally little is known of the seasons in which they spawn, of the places in which they cast their spawn, and still less of the time which the spawn after it is cast takes to vivify. Nobody, so far as we have been able to ascertain, has ever seen the eggs of soles, turbot, plaice, and other like fish after their extrusion under natural circumstances from the parent fish. A little more is known about the spawning of round fish. The spawn of the herring is certainly attached to small shells, sea-weed, and other substances at the bottom of the sea. Professor Sars has apparently proved that the spawn of the Gadidæ floats on the top of the water. The same thing has been shown by the Hon. S. F. Baird, of the United States Fishery Commission. . . . With these exceptions little is known of the spawn of sea-fish."

The Report goes on to state that more was known concerning the habits of the fry; that most young fish frequent the shallow, sandy, or muddy plains which are adjacent to the sea-coast, or the mouths and estuaries of rivers. But a study of the Appendices already mentioned shows how meagre was the supply of accurate information from which Buckland was able to draw at that time.

In 1880 was published *The Natural History of British Fishes*, by Frank Buckland. It consists of a popular account of each fish in alphabetical order, and contains a considerable amount of information, interspersed with anecdotes and personal experiences in the author's well-known manner. But from a serious point of view it is by no means so important as the official Report of 1879, already mentioned.

Dr. Francis Day's *Fishes of Great Britain and Ireland* was issued in parts from 1880 to 1884. It is enriched with fine lithographic plates from his own drawings of every British and Irish species known to the author. It contains a vast amount of information, and is one of the most valuable books of reference accessible to the student of the fishes of the British Islands. But with regard to the life histories of the fishes the information given is far from satisfactory, and by no means well arranged. It deserves mention here that both Buckland and Day were largely indebted to the personal observations of Mr. Matthias Dunn, of Mevagissey, in Cornwall, who throughout a long and busy life has perseveringly and very fruitfully applied himself to the careful study of the habits and life histories of the denizens of the waters near his home, and has made good use of the exceptional opportunities for collecting which the harbour of Mevagissey affords.

The systematic investigation by modern methods of questions relating to the fish-supply began in this country with the establishment of the new Fishery Board for Scotland in 1882. The old Fishery Board, whose official title was the Board of British White Herring Fishery, was dissolved. The first members of the new Board were:—Sir Thomas J. Boyd, *chairman*; John Guthrie Smith, Sheriff of Aberdeen, Kincardine and Banff, *deputy-chairman*; George H. Thoms, Esq., Sheriff of Caithness, Orkney and Shetland; Alexander Forbes Irvine, Esq., Sheriff of Argyle; Sir James Ramsay Gibson-Maitland, Bart.; Stephen Williamson, Esq., M.P.; Professor Cossar Ewart, M.D.; James Maxtone Graham, Esq.; James Johnstone Grieve, Esq.; Mr. Dugald Graham, secretary; Archibald Young, Esq., Advocate, Inspector of the Salmon Fisheries of Scotland.

The new Board being not only required to make suggestions for the improvement of the Fisheries, but being empowered also to take such measures for their improvement as the funds under their administration and not otherwise appropriated might admit of, and taking into consideration also the important practical results obtained by the U.S. Commission of Fish and Fisheries, decided to institute investigations into the habits and life-history of some of the more important food-fishes, such as the herring cod, ling, haddock, mackerel, sole, plaice, and flounder.

The following questions are mentioned in the First Annual Report, 1883, as deserving careful investigation:—

(1) The food, life-history, distribution, and migrations of useful fishes.

(2) The nature of the feeding and spawning grounds of food fishes.

(3) The period of spawning, nature of the ova, the time required for, and the conditions favourable to, hatching.

(4) What means can be adopted for the protection of fish during their early stages of growth, and what can be done to prevent the destruction of immature fish.

(5) What new useful fishes (such as the American shad and the land-locked salmon) can be introduced, and how far the supply of our present forms can be increased by artificial cultivation or protection during the spawning period.

(6) The influence of atmospheric variations, and of the changes of the temperature of the water, and of currents, on the presence and migrations of fish, and the

nature and depth of the water where fish commonly abound.

(7) The special enemies of useful fishes, and the causes of the disappearance of fish from certain districts.

As the artificial cultivation of cod or other fish required more appliances than the Board could command, they determined to commence with the investigation of the food and early life-history of the herring. They therefore applied to the Home Secretary to ask the Lords of the Admiralty to grant the use of a steam pinnace. The application was declined.

From the Second Report of the Board, giving its proceedings in 1883, published in 1884, we learn that in the late summer of 1883 the Admiralty consented to the use of the *Jackal*, a steamer usually employed in fishery protection service, for a preliminary inquiry into the herring and herring fishery. The expenses of this inquiry were to be met out of the sum voted for travelling expenses, and a small wooden laboratory on the coast of Ross-shire, belonging to Mr. Romanes and Professor Ewart, was lent by them for the work of the Board.

At the suggestion of Professor McIntosh, of St. Andrews, who has been all his life a keen student of marine zoology, the Board agreed to co-operate with him in providing for the expense of fitting up a small building on the shore there as a marine laboratory, in which researches on food-fishes could be carried on. With the sanction of the Treasury a sum of £335, was devoted by the Board to this purpose, and Professor McIntosh commenced experiments and observations on the floating eggs of flat-fishes. The Scientific Appendix to this Report includes a note by Professor McIntosh on these earliest researches at the St. Andrews Laboratory, consisting of the artificial fertilisation of the eggs of the cod and flounder and a few other fishes.

In March, 1884, Professor Ewart made an examination of the Ballantrae Bank, reputed to be a herring spawning bed. It was found to be covered with herring spawn, and the results of this examination were the most valuable obtained up to that time by the scientific inquiries of the Board.

The Treasury only sanctioned £900 for the scientific work from funds already in the hands of the Board, chiefly herring-brand fees. £300 of this was required to meet expenses already incurred, £335 for St. Andrews, so that, the balance being very small, scientific work was almost suspended in the summer of 1884.

In 1883 a Royal Commission was appointed to inquire into the injuries alleged to be inflicted upon line and drift-net fishermen by the use of the trawl-net and beam trawl in the territorial waters of the United Kingdom. A sum of £200 was granted to this Commission for the purpose of conducting scientific observations upon the results of the use of the beam trawl; and in January, 1884, Professor McIntosh was appointed to make these observations. The members of this Commission were:— John William, Earl of Dalhousie; Edward Marjoribanks, M.P.; Thomas Henry Huxley, F.R.S.; William Sproston Caine, M.P.; Thomas Francis Brady. Ninety-three hauls of the trawl on board an ordinary steam trawler were made under the observation of Professor McIntosh, who reported to the Commission in November, 1884. His report was printed as an appendix to the Report of the Commission, published in 1885.

Professor McIntosh's cruises were made off the mouth of the Firth of Forth and off Aberdeen. Three days were also spent in trawling in a private steam yacht off Scarborough, and two days in St. Andrews Bay, in the *Medusa*, belonging to the Granton Marine Station. His report contains a deal of information, though, as might be expected, it is by no means so precise as that obtained by subsequent researches of a similar kind. It contains tables showing the fish captured in the various hauls under three heads—saleable fish, immature fish, and unsaleable fish. The latter title applies only to those species of fish which are entirely unmarketable, for which there is no demand for any commercial purpose: they are the frog-fish (*Lophius piscatorius*), two kinds of dog-fish, and a few common shore fishes of small size. The title "immature fish" is applied to those individuals of marketable species which were so small as to be useless for the market, and therefore has no reference in this Report to the condition of the fish with respect to spawning.

Thus all that can be got from the tables is the proportional numbers of the individuals thrown overboard after capture, and of those kept for the market. On the fishing grounds where the observations were made true soles are very scarce—only 78 were taken, and none were rejected; also of turbot and brill none came under the heading "immature." One-fourth of the total number of plaice captured were rejected from their small size; while of common dabs and long rough dabs, ten times as many were thrown overboard as were taken to market, these being rather small fish even when adult. However, the actual waste of fish of valuable kinds—with the exception of common dabs and long rough dabs, which are of very little commercial importance—is shown to be very small indeed. The only species in which the waste, if the small specimens do not survive when returned to the sea, is serious, is the plaice.

The Report of the Commission itself was a most important one, not only from the nature of its conclusions and recommendations, but from the fact that many of them have been put in force by legislation. It is worthy of note that, in consequence of ill-health, Professor Huxley was unable to take any part in drawing up the Report, and therefore did not share in the responsibility for its conclusions and recommendations. The Report states that, in the absence of reliable statistics by means of which the then supply of fish could be compared with that of previous periods, the Commission was unable to estimate the degree to which diminution had taken place, although it considered that the supply of certain kinds of fish in certain places in the territorial waters had diminished in recent years. The Commission recommended that statutory powers and means should be given to the fishery authorities to enable them to collect fishery statistics. It was of opinion that the productiveness of the fishery grounds should be regularly and periodically examined by competent persons, and that all circumstances bearing upon fishery questions should be systematically investigated. The Commissioners thought that the proposed investigations of the Scottish Fishery Board were of a useful and practical character, and worthy of the expenditure of public money. They recommended that experiments should be made to test the effect of trawling, and for this purpose power should be given to the authorities to prohibit trawling in territorial waters when and where they thought fit. Scotland and Ireland possessed Fishery Boards, but England had no analogous authority. Such an authority, the Commission declared, should be created for England at once; and on it, as well as on the Scotch Board, should be conferred the regulating powers already possessed by the Irish Board. They also thought that one central authority should be created for the United Kingdom, but in the meantime the Scottish Board should have the powers and funds it asked for. The latter recommendation has been carried into effect, but the former has been neglected. The Commission recommended that, as a temporary measure, the large powers of a fishery authority in England should be conferred upon the Secretary of State for the Home Department, or on the President of the Board of Trade.

On the 31st March, 1884, the Marine Biological Association of the United Kingdom was founded and constituted at an influential meeting held in the rooms of the Royal Society, at Burlington House, London. Professor Huxley was its first president, and Professor E. Ray Lankester, who initiated the movement, became its honorary secretary. The Association immediately set about choosing a site for a well-equipped and permanent marine laboratory. The site chosen was one granted to the Association by the War Office, on the Citadel Hill, Plymouth, where the laboratory now stands. At the first annual meeting of the Association in 1885, subscriptions to the amount of £8,000 were announced; in 1886 the amount reached nearly £15,000 including £5,000 from H.M. Treasury; and in 1887 the laboratory was almost finished, and active work was commenced.

In October, 1884, the sum of £1,000 was placed by the Government from the Public Treasury at the disposal of the Scottish Fishery Board for scientific investigations. During the previous summer the scientific work of the Board had been in great part suspended. Nevertheless the Marine Station at St. Andrews was completed in the autumn of 1884, and researches into the natural history of food-fishes commenced there. In the same autumn Professor Cossar Ewart was sent to the United States to study the methods and operations of the Fish Commission of that country. In January, 1885, Mr. George Brook was appointed as a salaried naturalist to work under the instructions of the Board, and under his supervision a wooden marine laboratory was erected at East Loch Tarbert, on the Firth of Clyde. The Board had also the use of the Rothesay Aquarium for biological observations and experiments, and a small wooden laboratory on the shore of Cromarty Firth on the east coast of Scotland. Thus at the beginning of 1885 the Board had no less than four marine stations for investigation, besides the resources of the Natural History Department of Edinburgh University.

The investigations carried on in 1884–85 were principally observations on the spawning of herring and cod at Rothesay. These observations were published in the Board's Third Annual Report for 1884. A number of cod were observed spawning in March in the Rothesay Aquarium, and the eggs were found floating at the surface of the tanks; the fish merely swam about at random while shedding the eggs and milt. The same Report contains an account of the Marine Laboratory at St. Andrews, and work done there, the latter consisting of observations on the eggs of the viviparous blenny and other useless fishes, and on the eggs of the herring, the young of the ling, of the eel, and of cod. Mr. Brook contributes some notes, the most important of which is a short paragraph stating that certain eggs, sent by fishery officers attached to zoophytes, were not herring eggs. In the Second Report of the Board such eggs were figured as those of the herring, and important conclusions drawn from their occurrence as to the period during which herring were spawning on the East of Scotland. It is necessary to note this and other errors and their rectification, as showing the ignorance of essential facts which has obtained, and the need of patient research and experience for the gradual attainment of trustworthy information.

In the same year 1884 was opened a Marine Station on a small scale at Granton, near Edinburgh. The origin of this enterprise was the grant to the Scottish Meteorological Society of the surplus money from the Edinburgh Fisheries Exhibition of 1882. At the time both that society and the Fishery Board were anxious to carry on scientific investigations into questions affecting the sea fisheries. The Granton Station was organised and governed by Dr. John Murray, subject to the approval of the Scottish Meteorological Society. The establishment consisted at first of a small floating laboratory and a steam yacht, the *Medusa*, fifty-one feet in length. For some years, besides Dr. Murray himself, four scientific observers worked for this institution—the present writer and Mr. Henderson in zoology, Mr. Rattray in botany, and Dr. Mill in chemistry and physics.

The work of the Granton Station was of a more academic and less practical character than the work at that time carried on by the Scottish Fishery Board. I was engaged in the investigation of the eggs and development of sea-fishes, including food-fishes. In the summer of the same year I described for the first time in this country a pelagic egg and larva, afterwards proved to belong to the sprat. In the autumn I artificially fertilised herring eggs on the coast of Northumberland, and published a contribution to the knowledge of their development in the *Quarterly Journal of Microscopical Science*. In 1885 I published a paper on the pelagic eggs of the cod, haddock, whiting, and gurnard, the first account with exact measurements and figures of the pelagic eggs of these fishes in this country. Professor McIntosh described pelagic eggs of these and other fishes in the Trawling Commission's Report in 1885, and a short note in 1884, but without figures. In 1886 I published a comprehensive survey of the work done up to that time in the development of marine fishes. In the same year I also published the discovery of the hermaphroditism and the nature of the egg capsule in *Myxine glutinosa*, the hag-fish, which is so troublesome an enemy to fish and line fishermen on the north-east coast.

In 1887, I transferred my services to the Marine Biological Association at Plymouth, and since then little work of direct utility to the fisheries has been done by the Scottish Marine Station, the other members of the staff having been already obliged to seek more remunerative posts in 1885 and 1886. The work of the *Medusa* has, however, been continued on the west coast of Scotland by Dr. Murray and many men of science who have co-operated with him; and research has been continued from time to time both at Granton, where a laboratory on shore was obtained, and at Millport on the Clyde, to which place the floating laboratory was transferred; these researches have resulted in large additions to the knowledge of the marine fauna of the Clyde and to other branches of marine science.

A considerable amount of work was accomplished under the auspices of the Scottish Fishery Board in the year 1885–86, the principal contributors being Mr. Brook, Professor Ewart, Professor McIntosh, and Mr. Duncan Matthews. Mr. Matthews made an elaborate investigation into the question of varieties among the herrings of the Scottish coasts, with the object of ascertaining how far examination of these herrings confirmed or contradicted the conclusions reached with regard to the herrings of the Baltic by Dr. Heincke, of the German Fishery Commission, working at Kiel. The report of Mr. Matthews in the Fourth Report of the Board is very detailed and valuable, though it by no means settles the question. The most important items of the rest of the work, the results of which are published in the same Report, are observations on the herring fishery of Loch Fyne, determination of the species of Copepoda and other animals taken in Loch Fyne, valuable Reports on the food of the herring, cod, and haddock, by Mr. Brook, and a Report on the proportion of herrings and sprats in Thames and Forth whitebait. Work was also carried on at St. Andrews Laboratory by Professor McIntosh and Mr. Prince. The results of these inquiries are described in the Board's Fourth Report, published in 1886. In the same Report it is stated that, in consequence of the recommendations of the Beam Trawling Commission, above summarised, the Sea Fisheries (Scotland) Amendment Act, 1885, was passed, conferring upon the Scotch Board power to prohibit by bye-law trawling or any other mode of fishing in any part of the territorial waters of Scotland. Under this Act the Board made a bye-law prohibiting trawling in the Firth of Forth, St. Andrews Bay, and Aberdeen Bay, as an experiment for the purpose of ascertaining the result of the prohibition on the supply of fish on the grounds so protected. The Board then applied to the Treasury for funds to enable them to purchase a small vessel for trawling. The sum of £3,000 was granted, and the steam fishing-yacht *Garland* was purchased at the price of £2,500. This vessel was 92 feet long, 15 feet 10 inches beam, and 8½ feet draught. She was built of iron. She was fitted with a trawl of 25 feet length of beam, with which she was to trawl over the protected grounds in order that the number of fish obtained from them at different times might be carefully and accurately ascertained.

In the Board's Fifth Report, published in 1887, an account is given of the operations of the *Garland*. It was decided not to close Aberdeen Bay any further, but by new bye-laws the territorial area in the Moray Firth was closed, and the Firth of Forth and St. Andrews Bay areas were extended. Mr. W. L. Calderwood acted as naturalist on board the *Garland*, and Mr. Duncan Matthews superintended the course of the trawling observations from the University of Edinburgh, collating and tabulating the returns forwarded from the *Garland*. Mr. Brook had charge of the work on the west coast, while Professor McIntosh continued his studies on the life-histories of food-fishes at the St. Andrews Laboratory. Beyond the records of the experimental trawling observations, the description of scientific investigations forming Appendix F to the Fifth Report does not contain much of great magnitude and importance. Mr. Matthews contributes a second elaborate report on varieties found among herrings from the east coast of Scotland. He also gives an elaborate description of the skeleton of the herring. Additional papers on the food of fishes are given, namely of the whiting and young Gadidæ. The statistics of fish taken by the *Garland*, and landed by ordinary boats, are given in a number of detailed tables occupying 157 pages.

In 1886 certain departmental changes were made in the English public service with respect to business connected with the fisheries. The jurisdiction of the Home Office in respect of salmon and fresh-water fisheries was transferred to the Board of Trade by the Salmon and Fresh-water Fisheries Act, 1886. A Fishery Department of the Board of Trade was organised, at the head of which was placed an assistant secretary (Mr. G. Swainston). Mr. Berrington and Mr. Fryer, the inspectors of Fresh-water Fisheries at the Home Office, were transferred to the new department, and a third inspector (Mr. Malan), specially for sea fisheries, was also appointed. The new department publishes annually a return of statistics of sea-fish landed on the coasts of the United Kingdom, and a Report on the Sea Fisheries, in addition to the Report on Salmon and Fresh-water Fisheries, which was continued. But the department *has no power to make scientific investigations*, nor to make bye-laws or regulations affecting the sea fisheries.

The anomalous position of fishery affairs in England and Wales has been since still further increased by the Sea Fisheries Regulation Act of 1888, which is of a permissive character, and allows the Board of Trade to create Sea Fisheries Districts on the application of county or borough councils, to be under the jurisdiction of district committees formed partly by members of the county or borough councils, partly by outside members. The powers of such district committees are larger than any previously exercised by the Board of Trade. They can make bye-laws to regulate the fishing in the territorial waters of their district to any extent they please, and provide for their expenses out of the local rates. Such Sea Fisheries Districts have now been created round nearly the whole coast of England and Wales.

In August, 1887, the Marine Biological Association issued its first publication, the first number of its journal. This number contained a full description, with plans, of its fine laboratory at Plymouth, and a valuable detailed description of the fishing industry at the port of Plymouth by Mr. Walter Heape. The second number, issued in 1888, contains a paper on some preliminary investigations made by myself, on the local fauna and the ova of food-fishes. In this first paper was already solved the mystery of the male sole, and the question of the reproduction of that species, previously unknown. In 1885 it had been stated to the Beam Trawling Commission that no one had ever seen a male sole, that the female soles were caught, but not the males. It was found that the male soles were abundant enough, but had simply not been recognised, and I artificially fertilised soles' eggs for the first time.

In the Sixth Report of the Scottish Fishery Board, published in 1888, the chief feature is again the statistics of the *Garland* relating to trawling, and to the abundance of fish in areas where trawling was prohibited. The data are too voluminous to be easily discussed here ; but it is interesting to note that those who directed the observations were beginning to see that something more was required than merely collecting and comparing the totals of the fish captured. It was found that in 1887 more flat-fish were taken in the closed areas than in 1886. But it may reasonably be objected that in these two years the Fishery Board did not fully understand the problem which had to be solved. It prohibited trawling in certain areas, and then made observations to see if the fish increased in these areas. As a result the Scotch Board points out that the number at least of flat-fish was greater. The result in other words was that if fish were not caught they would remain in the sea. The problem that has to be solved appears to be a different one; it is, how can we maintain the total annual yield of the sea fisheries? It is a very simple remedy for the diminished yield of the fisheries to leave off fishing, and one not likely to be adopted while a margin of profit remains. The question is whether by certain particular restrictions the general supply can be increased, or at least prevented from diminishing, and this question was not at that time answered by the Scottish Board. It must on the other hand be admitted that the Board had some reason on its side in considering the question of trawling in relation to territorial and inshore waters, and how it affected the fishing which previously went on at scattered villages along the coast.

Perhaps the most important results of the operations of the *Garland* were the information subsequently obtained from her operations under Dr. Wemyss Fulton's guidance with regard to the life-histories of valuable fishes. The shorter papers included in the Sixth Report are of no striking importance; but one tracing the colour of "red cod"—*i.e.* the discoloration of dried cod-fish—to microbes, deserves mention.

The work of the Scottish Fishery Board in 1888, described in the Seventh Report, 1889, consisted, firstly, of a continuation of the laborious observations on the condition of the inshore fishing grounds, where trawling was prohibited; some observations on the "spawning grounds" of plaice and other fishes; systematic inquiries into the distribution and capture of immature fish; an examination of the trawling grounds to the west of the Hebrides, and certain special inquiries. In this year and the preceding, the scientific work was under the control of a Committee of the Board; and Dr. Wemyss Fulton, who began to work for this Committee in 1887, acted in 1888 as secretary to the Committee, and was entrusted with the organisation of much of the fishery research with very satisfactory result.

The fully equipped operations of the Marine Biological Association at the Plymouth Laboratory commenced in June, 1888; the staff consisting only of the Director of the Laboratory, G. C. Bourne, Esq., Fellow of New College, Oxford; his assistant, W. Garstang, Esq., B.A.; and the present writer. It should be clearly pointed out that the declared object of the founders of the Marine Biological Association was "to promote researches leading to the improvement of zoological and botanical science, and to an increase of our knowledge as regards the food, life-conditions, and habits of British food-fishes and molluscs" ; and this double purpose of pure scientific investigation on the one hand, and of special fishery study on the other, has been strictly adhered to by the Council in its management of the funds at its disposal. The Fishmongers' Company contributed £200 a year, raised later to £400 a year, to the Association, whilst Her Majesty's Government have given £500 a year in the years 1888–89, 1889–90, 1890–91, and £1,000 a year in the years following. Private individuals have given annual donations of £200 and upwards to promote special researches, and contributions have been received from other city companies and from the Royal Society. Besides the investigations noted in the present chapter, which have contributed largely to our knowledge of food fishes, the Plymouth Laboratory has to reckon, as a no less important outcome of its activity, a long list of scientific memoirs on the embryology and anatomy of marine organisms of all kinds, the result of researches made within its walls by British and foreign naturalists who have availed themselves of the facilities for study there provided.

In 1890 were published two elaborate memoirs on the development and life-histories of food-fishes, namely, "The Development and Life Histories of Teleostean Fishes," by Prof. McIntosh and Mr. E. E. Prince (*Trans. Roy. Soc. Edin.* xxxv., 3), and "A Treatise on the Common Sole," by myself. Of the first memoir, which is somewhat voluminous, the first ten sections have little direct bearing on fisheries, treating of the development of the eggs of fishes as a purely zoological subject. Section XI. is devoted to the embryonic larval and post larval stages of fishes and forms a valuable contribution to our knowledge of the eggs of fishes and the earliest condition of the young after hatching Section XIII., the last, is one of the most important, giving a full account of the previously unknown eggs and development of the cat-fish, *Anarrhichas lupus*, a fish which is common on the east coast, and sometimes eaten, though not of great value in the market. The memoir is illustrated by twenty-eight lithographed plates.

My memoir on the sole is illustrated by eighteen plates, to the production of which very great labour and expense were devoted. Nine of the plates are finely-executed chromo-lithographs, prepared from water-colour drawings made from life by an artist specially employed for the purpose. These plates illustrate the characters and appearance of the four British species of sole, the changes in the colour of the common sole on different grounds, and the position and relations of the breeding organs in their natural position as seen on dissection. The other plates illustrate the anatomy of the sole, and the eggs and transformations of the young in this and other species of flat fishes. The latter two sections of the four into which the memoir is divided contain a full and careful discussion of the natural history of the sole, and the bearings of this upon the production of soles for the market. The artificial propagation of the sole, which has been carried out only at the Plymouth Laboratory, is fully considered, and is shown to be beset with certain difficulties not met with in connection with other kinds of food-fish. These difficulties are chiefly caused by the remarkably small size of the male breeding organs or milts in the sole, a peculiarity to which was due the fact that previous observers failed to recognise the male sole at all.

We find from the Eighth Annual Report of the Scottish Fishery Board, published in 1890, that in 1889 the scientific work had been entirely superintended by Dr. Wemyss Fulton, acting under the instructions of the Board, the Scientific Committee having ceased to act. In this Report the trawling observations are discussed on the usual plan for the year 1889 and show a distinct decrease of fish in the closed areas—a somewhat different result from that originally anticipated. The most important part of the Report is Dr. Fulton's paper on the "Distribution of Immature Fish and their Capture by different Modes of Fishing," based upon observations specially made by the Board's investigation steamer *Garland*. This paper contains the first attempt made to ascertain the *size* at which each species of food-fish becomes mature—that is, the size at which it breeds for the first time. This was done merely by finding the sizes recorded of the smallest ripe, or nearly ripe, specimen of the various species examined. The distribution of the fish above and below these limiting sizes is lucidly described, and we have here the first contribution of importance to our knowledge of the differences among the different kinds of fish as to the regions inhabited by the young. It was previously stated that the inshore grounds were nurseries for young fish. It was now proved that this is true only of certain kinds of fish, and especially of the plaice. Another important contribution by Dr. Fulton deals with the relative numbers and sizes of the *sexes* in food-fishes.

The Report of the Board for 1890, published in 1891, contains nothing very novel, but important continuations of the investigations described in the preceding volume of the series. The records of the trawling experiments of the *Garland* are continued, and also some special fishery statistics in continuation of those of former years. Dr. Fulton publishes a second paper on immature fish, giving the result of an experimental investigation of the problem whether the small fish are killed by capture in the great trawl or in the shrimp trawl, or whether they are alive and survive if returned to the sea. He concludes that in great trawls the flat fish are usually alive and not killed while the round fish are fatally injured, and that in the shrimp trawl the small fish captured are uninjured.

In the year 1890 an important fishery survey was organised in Ireland. The Royal Irish Academy had in previous years made explorations of the sea-bottom off the south-west coast of Ireland by the agency of the Rev. W. Spotswoode Green. In 1887 the Royal Dublin Society, whose function is to promote industries, rather than pure science, began to utilise Mr. Green's services in the examination of the condition of the fisheries in the south and west of Ireland. At the end of 1889 the Chief Secretary for Ireland approved of a suggestion that the Society should organise a survey with the object of ascertaining the amount and distribution of the fish supply on the west coast. The estimated cost was found by the Society to be £1,200 per annum for two years, and the Government agreed to provide half the money, the Society the other half. The execution of the project was entrusted to the Rev. W. S. Green, who conducted a fishery surveying cruise in the SS. *Fingal* in the spring and summer of 1890. Mr. Green was appointed director of the Survey, Professor Haddon, naturalist, and Mr. T. H. Poole, C.E., surveyor. As the survey was commencing, Mr. Green was appointed one of the inspectors of Irish Fisheries, but this made no difference in the plans. A narrative of the first cruise was published in the Report of the Royal Dublin Society for

1890; but the complete results of the two years' work were not published till 1892, when they were printed in the Report of the Council of the Society for 1891, and in the Proceedings of the Society. This statement of results, under the title, "Report on the Results of the Fishing Operations of the Survey," was prepared by Mr. Ernest W. L. Holt, who bore the principal share in the natural history work in the two cruises of 1890 and 1891. The plan of operations in the natural history department was devised by Professor Haddon, and he took charge of the work on board ship for two months in 1890, but not in 1891. Mr. Holt's Report consists first of a list of the stations examined, with a list of the fish caught at each, and an indication of the invertebrates taken with them; secondly, of a record of all the fish caught under the heading of each species; thirdly, of a discussion of the scientific evidence on economic questions afforded by the examination of these fish. In this last part of the Report we have the determination for the west coast of Ireland of (1) the spawning period of fish and the distribution of the spawning fish; (2) the limiting sizes of immature fish and comparison of the habitats of mature and immature fish; (3) the effect of different nets upon the capture of immature fish; (4) the food of fishes. With respect to the definition of immature fish in the several species, Mr. Holt makes an improvement on Dr. Fulton's method. Dr. Fulton ascertained the smallest size of ripe and nearly ripe fish without regard to sex, but mentions at the same time that the smallest ripe specimens in nearly all instances were males. Mr. Holt gives tables in which the greatest and least lengths of ripe and nearly ripe specimens are recorded for the two sexes separately, and then in discussing the distribution of mature and immature forms, divides them by the size of the smallest ripe *female*. Mr. Holt's report also contains in many cases information as to the habitat of the very young individuals of several species which do not pass their young stages in shallow water, and which in these stages had not been obtained before—*e.g.*, lemon sole (*Pl. microcephalus*), pole dab (*Pl. cynoglossus*), and others. Mr. Green at first announced that the young of such forms obtained in very deep water were the young of the common sole; but when this conclusion was challenged by myself from my own experience, the mistake was discovered and acknowledged. The results obtained by the Survey are very valuable, and will form a most useful basis for attempts to develop the deep-sea fishery on the west coast of Ireland. If the Government had provided means for a similar survey of the east coast of England and the North Sea, the result would have gone very far to settle the question of immature fish which was agitating the industry in that region. As it was, the conclusions obtained on the east of Scotland and the west of Ireland could not be applied directly to the east of England, and in consequence the Marine Biological Association endeavoured, with a single naturalist (Mr. Holt) and without a surveying ship, to do there what was thoroughly done with special Government aid on the west of Ireland.

In the Tenth Annual Report of the Scottish Fishery Board, published in 1892 and relating to 1891, much space is as usual occupied by the tables of records of the statistical observations made by means of the *Garland* and otherwise. The trawling experiments of the *Garland* showed again a considerable decrease in the abundance of food-fishes in the waters of the Firth of Forth and St. Andrews Bay, closed against beam-trawling. Following are extracts from Dr. Fulton's remarks:—"It is clear from the analysis of the results of the trawling experiments since 1886, that the prohibition of beam-trawling within the Firth of Forth and St. Andrews Bay has not been followed by the increase in the abundance of flat fishes within these waters which was anticipated." As an explanation it is pointed out that the spawning fish do not spawn in the protected waters, but are on the other hand captured outside by the trawlers; and that immature fish of the majority of species are to be found in greatest numbers outside the territorial limit up to a distance of ten or twelve miles from shore. In the same Report Dr. Fulton has an interesting paper on the decrease in the supply of fish, and the remedies for it, especially in relation to sea-fish propagation and culture. In 1891 it was decided by the Board that a sea-fish hatchery should be erected and equipped at Dunbar, after the pattern of the hatchery of Captain Dannevig at Flödevig, Arendal, Norway. Dr. Fulton went to examine the arrangements at Flödevig, and the construction of the establishment at Dunbar was commenced. The whole of the expenditure has been met from the ordinary Government grant to the Scotch Board for scientific investigations, but an additional £1,500 is asked from the Treasury in order to enclose creeks and convert them into sea-ponds.

The work performed by the staff of the Marine Biological Association in 1890, 1891, and 1892, is recorded in the numbers of the *Journal* published in those years. It includes a comprehensive account of the reproduction and development of the conger, which contains the results of experiments and observations made by means of the aquarium and extending over two years. These researches brought to light or confirmed several important and remarkable facts concerning the history of this fish, which will be found detailed in their proper place in the present work. The value of the aquarium is also shown in the results obtained in the experimental investigation of the growth of fishes, especially of the flounder, a number of specimens of which were kept alive for three years, their size and condition with respect to sexual maturity being examined from time to time.

Another research of great interest was that of Mr. William Bateson on the various modes in which different fishes seek their food, and the possibility of inventing some cheap and effective form of artificial bait for long liners.

It should be borne in mind, in comparing the work of this Association with that of the Scottish Fishery Board, that its total annual revenue has been from £1,000 to £2,000, and that it has not been possible to devote more than half of this to fishery investigations or to employ the services of more than one investigator in such work until 1891, when by means of a special donation from Mr. J. P. Thomasson of £250 the services of Mr. E. W. L. Holt were also secured. This naturalist, who did such good work in the Irish survey, was stationed at Grimsby, where the local Marine Fisheries Society placed their small but useful establishment at his disposal. His first work consisted in the careful collection of evidence as to the size at which the most valuable species of flat fish in the North Sea became mature. Evidence as to the same question with regard to fish of the same species at Plymouth was collected by myself, and the results in the two districts differ, a fact which constitutes one of the chief difficulties in framing restrictive legislation in reference to the capture of undersized fish.

The possibility of establishing a fishery for anchovies engaged the attention of the Council of the Association, and by means of small meshed nets obtained for their capture, and by collecting anchovies taken in the nets of the pilchard fishermen, an inquiry was carried on concerning the abundance and the migrations of these fish in the neighbourhood of Plymouth. The facts ascertained compared with what is known concerning the annual occurrence of the fish in the Zuyder Zee and other inlets on the coasts of Holland, strongly suggest a regular migration of anchovies between the latter district and the English Channel.

In the Eleventh Report of the Scottish Fishery Board published in 1893 it is stated that actual work at the Dunbar hatchery had not commenced in 1892. Of the scientific investigations described perhaps the most striking are those of Dr. Fulton on the movements and rate of growth of plaice and other fishes in the Firth of Forth and St. Andrews Bay. The method followed in this inquiry was to mark fish by attaching a numbered label to each when captured, and then to set them free again. The chief difficulty was to invent a mode of marking which should be sufficiently permanent, and yet not interfere with the health and growth of the fish. Dr. Fulton after many trials obtained the most satisfactory results from using small brass labels fastened by black silk cord round the root of the tail. Of plaice the great majority marked were immature, and about 1 in 10 were recaptured. An interesting result was obtained on comparing the places of recapture with those where the fish were liberated : the plaice were found to move in definite directions, westwards on the south side of the Firth of Forth, eastwards on the north side. Cod were found to move to much greater distances than plaice. The information gained by the experiments concerning the rate of growth though of some value, is not perfectly satisfactory owing to the fact that the cord by which the labels were attached caused injury to the tail and the fish seemed usually to have suffered in health.

The Report contains further contributions by Professor McIntosh to the knowledge of the life-histories of the food-fishes, and various other papers on the rate of growth of fishes and the zoology of the sea.

The Twelfth Report, published in 1894, contains the first account of operations at the Dunbar hatchery, together with a complete description of the establishment from the pen of Dr.

Fulton. The hatching work was directed by Mr. Harald Dannevig, son of the Captain Dannevig, of Arendal, who has made the practical hatching of sea-fish his special study for so many years. Over twenty-seven million plaice eggs were obtained from the spawners, and over twenty-six million fry were obtained and "planted" in the sea. The arrangements of the Dunbar hatchery are interesting, and the chief features are as follows: There is a spawning pond forty and a half feet long, eighteen to twenty-six and a half feet broad, eleven feet deep. This is on a higher level than the hatching house. Water is supplied to it by means of steam pumps, and the overflow passes through a filtering chamber, where the floating eggs are retained, and then down a shoot on to a water-wheel, which works certain simple machinery for agitating the hatching boxes. The pumps supply also water from the sea to the hatching boxes, the water being filtered on its way. The fish are placed in the spawning pond when nearly ripe, and allowed to spawn of their own accord.

The remainder of the scientific part of the Twelfth Report, although valuable and important, does not indicate any great novelties in the operations of the Board. Prof. McIntosh and his pupils and assistants describe as usual the results of various studies of problems connected with the life histories of the more valuable fishes in their natural condition in the sea, and these indicate steady progress in the investigations carried on at the St. Andrews Laboratory. Dr. Fulton gives a report of some definite and precise experiments on the effect of the size of the mesh of the trawl on the sizes of the fish captured. These experiments were carried out by the *Garland*, and consisted in fastening outside the trawl net, round its end, a net having meshes of only half an inch square. The fish which escaped through the trawl were retained by the outer net, and the comparison of those found in the trawl and outside it is very interesting. Trawls with meshes of various sizes were tested in this way.

It will be seen from the above summary that the organisation of the scientific department of the Scottish Board in the year 1894 consisted of (1) The Superintendent in Edinburgh and the steamer *Garland* employed for special experimental inquiries at sea, and for the examination of the closed and unclosed trawling grounds; (2) the hatchery at Dunbar under the control of a special manager, but subject to the supervision of the Superintendent; (3) the laboratory at St. Andrews, where Professor McIntosh and a succession of pupils and assistants from the Universities of St. Andrews and Edinburgh carried on the more purely zoological researches. Special investigations of the physics of the sea, circulation of water, density, temperature, &c., were also carried on by experts not on the permanent staff of the Board, on H.M.S. *Jackal*, commissioned to perform fishery service.

During the years 1893 and 1894 Mr. Holt continued to work in the service of the Marine Biological Association at Grimsby, and the staff of the Laboratory at Plymouth. Much of the work had reference to the question of the capture and destruction of immature fish, to which attention was still more strongly drawn by the appointment in 1893 of a Select Committee of the House of Commons to inquire into it. Mr. Holt's Report in the *Journal* gives extensive statistics of the number of immature and mature fish of certain kinds brought to the Grimsby market. At Plymouth I was largely occupied in studying microscopically the development of the egg in the roes of fishes, and the condition of the roe before and after spawning, in order to obtain a more complete knowledge of the various conditions seen in different individuals at different times of the year. I also spent much time in the endeavour to overcome the difficulty of rearing the delicate newly-hatched young of food-fishes in confinement. It is generally admitted that the benefit effected by merely hatching the eggs and then consigning the larvæ to the sea, is not likely to be so great as that which might be secured by protecting the young fish in their early and delicate stage. Various papers on points connected with the natural history of fishes are contained in the recent numbers of the Association's *Journal*.

CHAPTER II

THE CHARACTERISTICS OF VALUABLE MARINE FISHES AND THE REGIONS IN WHICH THEY LIVE

THE word fish is often used to include nearly every creature that lives in the sea. We talk of star-fishes and of shell-fish, as well as of fishes in the stricter sense. The oyster and the lobster are both called shell-fish, notwithstanding the great difference between them in the matter of legs and claws. The passive, transparent objects which we call jelly-fishes have no resemblance to either a star-fish, oyster, lobster, or fish. Then again the whale and the porpoise are often called fishes, and supposed by many people to be quite correctly so called. But in order to learn something about the history and origin of these creatures and how they live, we must take the trouble to study the differences between them. We must find out how many principal kinds of animals there are in the sea, bringing together those that are alike and separating those that are unlike. This is the first step towards the recognition and identification of the various kinds in all the stages and periods of their lives. What is found to be true of one kind of animal or one kind of fish may not be true, and in fact very often is not true, of another kind. A correct knowledge of certain facts about the history of some particular fish may be and often has been seriously misunderstood, when the various kinds have not been properly distinguished.

Now in the first place there is one grand difference among animals in the construction of their bodies, namely, that some possess a back-bone, and others do not. We ourselves have a back-bone, and likewise beasts, birds, reptiles, frogs, and fishes.

Star-fishes, jelly-fishes, oysters, lobsters, and many other creatures belong to the great tribes of lower animals which have no back-bone. Back-boned animals never have more than two pairs of limbs, corresponding to our arms and legs, while the lower animals, as for instance insects, crabs, and lobsters, may have a great number of legs.

Back-boned animals are better known to most people than the lower animals. In fact with the exception of a few like the oyster and lobster, which are eaten as delicacies, the lower animals are usually regarded with more or less disgust. But we all know enough about the back-boned animals to distinguish between beasts, birds, reptiles, and fishes. We know that beasts have hair, birds have feathers and wings, reptiles and fishes are usually covered with scales. The scales of a reptile however are fixed, and do not come off easily like those of fishes. But the most important peculiarity of fishes is that they have gills which are placed at the sides of slits or openings behind the head, through which water passes from the throat to the outside of the body. Now a whale or a porpoise, although its body is shaped much like that of a fish, has no gills and no scales. These creatures are therefore not fishes, not of the same class of animals as mackerel, herring, or shark. What then are they? Examination shows that they have some traces of hair on their skins. They also breathe air by means of lungs just as we do. Every one knows that a whale spouts or blows, which means that it comes up to the surface of the water to breathe out the air in its chest, and takes in a fresh breath before it dives again. But this is not all. The whale and porpoise and other such creatures bring forth their young alive and suckle them afterwards, exactly in the same way as dogs or cats or other quadrupeds. They belong therefore to the tribe of beasts, although they live entirely in the sea, and never, as seals do, emerge on to the shore. They are beasts which have left their kindred and taken to a sea-faring life.

The lower animals which inhabit the sea form five very distinct great tribes, differing from one another in structure of body and mode of life, as much as they differ from fishes. The following well-known animals are representative examples of these tribes: lobster, oyster, lug-worm, star-fish, and jelly-fish. The lobster belongs to the tribe of Crustacea, sufficiently distinguished by their hard jointed outer covering or shell, and their numerous pairs of jointed legs. The oyster represents the Molluscs, of which the principal sub-tribes are the bivalves having two shells hinged together like the oyster and mussel, the univalves like the periwinkle or whelk, and the cuttle-fishes and squids which have no external shell and are active swimmers. Of Worms there are myriads of different kinds. The creatures of the star-fish tribe are called Echinoderms, or spiny-skinned animals, and occur in three principal forms, the rayed form like the star-fish, the globular form like the sea-urchin, and the cylindrical form like the sea-cucumbers. The animals represented by the jelly-fish also have the radiate or star-like structure, presenting a number of similar parts arranged round a centre. The tribe includes besides the floating jelly-fishes, the sea-anemones, which are attached by a flat base to rocks, stones, and shells, and the zoophytes, which are commonly supposed to be

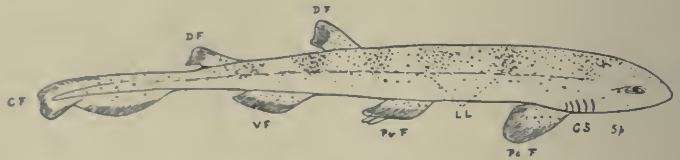


FIG. 1.—The Smaller Spotted Dog-fish. **D.F.** dorsal fin; **V.F.** ventral fin: **C.F.** caudal fin; **Pc. F.** pectoral fin; **Pv. F.** pelvic fin; **G.S.** gill-slits; **Sp.** spiracle; **L.L.** lateral line.

The outline figures in this chapter are based upon the illustrations of Day's *British Fishes*.

sea-weeds and which grow from a fixed base in a branching plant-like form. In addition to all these there are the sponges and the minute microscopic creatures which belong to the animal kingdom and are simple particles of living substance which multiply by self-division. The plants of the sea consist of the well-known sea-weeds, and a vast multitude of different kinds of minute green or brown particles which are suspended freely in the water. For the purpose of the present work these various tribes of creatures will only be mentioned in their relation to the life of fishes, and a general survey of the characteristics of the principal British marine fishes is now to be given.

Fishes then may be defined as aquatic animals which have a backbone or some rudiment thereof, which breathe water by means of openings from the throat behind the mouth, and which usually possess paired and unpaired fins. The gills of fishes are in most cases rows of delicate ridges or of projections on the sides of the gill openings (G. S., Fig. 1.); the blood flows through these ridges or projections, and is thus exposed to the influence of the water which is constantly passed through the gill-openings from the mouth. The fins are thin projecting folds of skin supported by movable hard firm rods called fin-rays. The unpaired fins are in the middle line between the two similar halves of the body, there are some on the back called the dorsal fins, some on the belly called the ventral fins, and one at the hinder end of the body, namely, the tail-fin. The paired fins are on the sides of the body, and attached by a short base. There are never more than two pairs, corresponding to our own arms and legs, or to the forelegs and hindlegs of a quadruped. The fin-rays in fact represent in a general way the toes or fingers of the limbs of the higher animals, while in fishes the long limb projecting from the body is not required, and is represented only by the bone or cartilage at the base of the fin. The front pair of fins corresponding to the arms of the human body are always placed close behind the gills and may be called the breast-fins or *pectoral* fins (Pc. F., Fig. 1.). The second pair are placed nearer to the lower edge of the body, and in many fishes are situated in their original position far back near the vent, as for instance in a dog-fish or salmon, while in many others they are below or even in front of the breast-fins, as for instance in the mackerel or cod. These fins, whatever their position, may be called the *pelvic fins* (Pv. F., Fig. 1.), while they are sometimes called abdominal fins or throat fins according to the part of the body in which they are situated. The organs of sense with which we are familiar in higher animals, namely, nose, eyes, and ears, occur in a well-developed condition in most fishes, but with certain important differences in structure. The nostrils as a rule have no posterior communication with the throat, but are merely pits opening on to the surface of the skin. The ear consists only of the essential apparatus of hearing, a closed cavity hidden in the side of the skull, and not connected with structures externally visible. In addition to these there is generally an additional sensory apparatus which is very characteristic of fishes, and which furnishes important marks for the recognition and classification of species. This apparatus consists usually of tubes in the skin opening by rows of pores on to the surface, and containing in their walls minute structures connected with the ends of nerves. It is probable that the function of this apparatus is to enable the fish to perceive movements of the water such as those caused by the passage of another fish, but very little is known with any certainty on the subject. Whatever the function the general arrangement of the tubes is very constant: there is usually one down each side of the body from the gills to the tail, and the course of this being visible externally forms what is called the *lateral line* (L.L., Fig. 1.). In front this tube divides into several branches on the head, but these are not usually conspicuous on the surface.

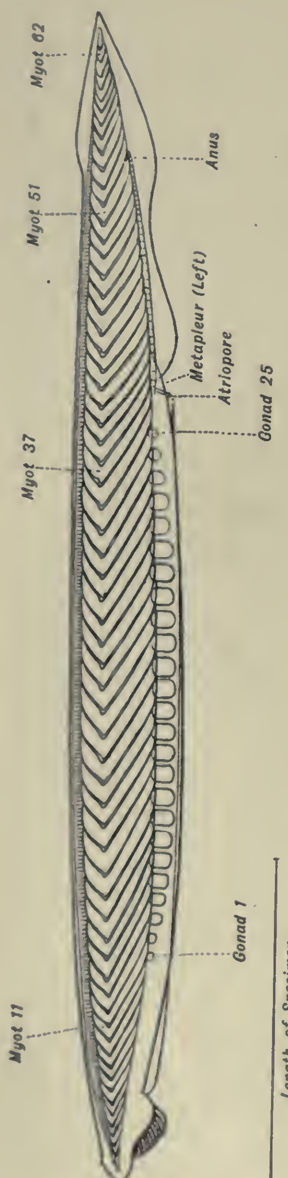


FIG. 2.—The Lancelet, or Amphioxus, an enlarged figure from a live specimen obtained at Plymouth. Myot = Myotome, or muscle-segment. Atriopore, the opening of the chamber in which the fore part of the gut with the gill-slits are situated. Gonad 1–25 the generative organs. Metapleur, the left of the pair of keels which run along the ventral side of the body; the reference line indicates the end of the left metapleur. The intestine and other internal organs are not shown.

The class of fishes consists of a number of very distinct orders which differ very widely from one another, and in some of which many of the characters above described are wanting. These characters in fact are only found all together in the fishes of the higher orders, with which we are most familiar, and which include the kinds to be chiefly considered in the present work. There are three orders which are of no importance commercially in this country. One of these may be called the lung-fishes, because although they have gills and fins they are provided with primitive lungs, corresponding to the air-bladder of other fishes, and with these to a limited extent they breathe air. None of these are European. Another order contains the lampreys and the curious hag-fish or borer which is familiar enough to line fishermen of the north-east coast of Britain. These have no paired fins. Their mouth is suctorial, and their gill-passages instead of being wide slits are in the form of pouches which open on the sides of the neck by small holes or by tubes leading to a single hole. A third order contains only a singular and much simplified creature called the lancelet or *Amphioxus*. The structure of this creature is shown in Fig. 2. It has no side fins no bones, no gristle, and properly speaking no head. It has no eyes, hearing organs or smelling organs like those of other fishes, but a single rudimentary eye and one simple nostril: it has no distinct brain. But still it has two of the most essential organs of a fish: a rudiment of a back-bone, and gill-slits. The former is a rod of laminated tissue running from one end of the body to the other, the latter are very numerous slits in the sides of the gullet, but they open into a gill chamber which communicates with the exterior by a single small aperture. The lancelet is common enough on our southern shores. It is only two inches long, is very transparent, and buries itself in the sand. We shall not need to consider these three orders any further in the present work.

Among the fishes which have a commerical value are members of two very distinct orders, dog-fishes and skates or rays on the one hand, and scaly fishes, such as the herring, the plaice, and the cod on the other. In the first order the skeleton contains no true bone, but consists of cartilage, or gristle which is soft and elastic. The skin is furnished not with scales, but with bony spines, plates, or tubercles which contain lime, and are in consequence hard and strong. The arrangement of the gills is very different from that seen in scaly fishes. There is no gill-cover, but five separate gill-slits open on the surface of the skin in the neck region, and can be seen to expand and contract regularly while the fish is alive. There is also usually a smaller opening from the throat, known as the spiracle, and situated just behind the eye. Another peculiarity of these fishes is the position of the mouth, which is a wide transverse slit on the flat, lower surface of the head. In other words, the snout projects usually to some distance beyond the jaws and terminates in a point. The fin-rays in these fishes are rods of gristle or cartilage with very numerous joints, and in addition to these there is beneath the skin of the fins a layer of fine horny fibres. The second pair of side fins or pelvic fins are always placed close to the vent. The tail has a characteristic form, consisting of two unequal lobes, of which the upper is the longer: the spinal column is bent up at the base of the tail, and continued into the upper lobe.

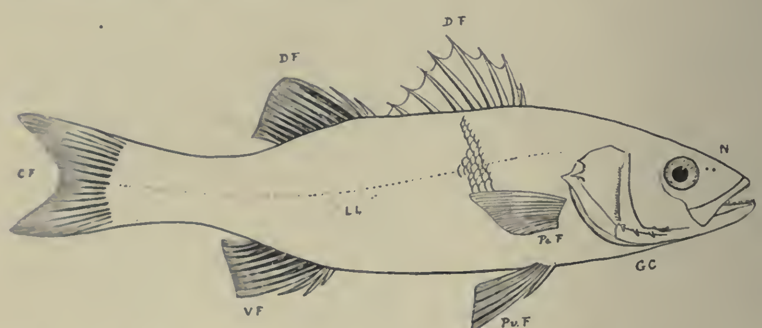


FIG. 3.—The Bass, as example of the bony fishes. **D.F.** dorsal fin; **V.F.** ventral fin; **C.F.** caudal fin; **Pc. F.** pectoral fin; **Pv. F.** pelvic fin; **L.L.** lateral line; **G.C.** gill-cover; **N.** nostrils of right side.

Bones and scales are the chief characteristics of the scaly fishes, although in some the scales are almost or entirely absent, as for instance in the eel. The scales overlap one another like the tiles of a house, and the larger part of each is imbedded in the skin, only the smaller hinder portion being exposed The tube of the lateral line pierces a longitudinal series of special scales, and to each of these scales corresponds a pore opening into the interior of the tube. The mouth is usually at the end of the snout and provided with bony jaws and teeth. The gill-cover, a broad plate on each side behind the head supported by bone, covers over the chamber in which the gills are contained and ends in a free edge behind. In the gill-cavity are the gills, which are four double fringes of red processes attached to four slender columns consisting chiefly of bone. These columns form part of the sides of the throat, and they are separated from one another by five slits, through which the water passes from the throat over the gills into the gill-chamber, and then out at the gill-opening. The slits correspond to those of the dog-fish, and the columns supporting the gills to the partitions between the slits in the dog-fish.

Between the gristly fishes, namely sharks and rays, and the familiar bony fishes there is a tribe of fishes which have some of the characters of both. They form all together a wonderful series of steps from the structure of one set to that of the other, but are on the whole nearest in characters to the first division of the true bony fishes, that is to such fishes as salmon or herring. The only one to be mentioned here is the sturgeon. This fish has a gill-chamber and gill-cover like a bony fish, but it has not scales of the ordinary kind. In their place the skin is provided with large plates of true bone in shape like large scales, but much thicker. These form a row along the ridge of the back, and two rows along each side. The fin-rays are all of the soft kind, that is to say, composed of numerous joints and therefore flexible, except the first of the breast-fin which is thick and rigid. The second pair of side fins are far back. There is one dorsal fin, quite short and small, placed behind those just mentioned. The tail, like that of a dog-fish, has a long upper lobe, into which the back-bone is continued. The snout is much produced, and rather broad and flat : underneath it in front of the mouth are four slender fleshy barbels. The mouth is rather small and round, and the jaws are capable of being protruded considerably. The sturgeon grows sometimes to eighteen feet in length, and is frequently taken in the North Sea, or at the mouths of our large rivers. It occurs in greater numbers in the river Volga, and is found also on the east coast of America. Several other species of sturgeon are known, and they all spawn in large rivers and descend to the sea only for a time in winter.

Among the creatures which we distinguish in the first place generally as fishes, and which resemble one another, and differ from other animals in the characters which have been mentioned above, there are, as every one knows, a multitude of different kinds, the individuals of which do not require further distinction. It is not necessary or possible to pay much attention to the trifling details in which one herring differs from another, or one mackerel from another, or one skate from another. It is sufficient to speak of so many mackerel or so many skate, or of a mackerel or skate of such a weight and such a size. We know that as an almost invariable rule fishes, like other animals, exist in these distinct kinds which are always recognisable, and capable of being distinguished from one another. In each of the divisions which have already been defined there are a great number of these distinct kinds or species. But within each division again there are subordinate groups of species, and in following out the history of the various species it is necessary to have some acquaintance with these further and subordinate groups. The species in fact are not separated from one another by differences of equal degree, but form natural families, each of which includes a number of species distinct enough from one another, but having a family resemblance. Thus the pilchard, herring, and sprat are much more like one another than they are to the species of another family, such as the cod, haddock, and whiting. Again, even within the family all the species are not equally different from one another, but form still smaller natural groups, which the naturalist calls genera. For example, the cod, haddock, and ling all belong to one family, which we may speak of as the cod family, but the cod and haddock are more similar to one another than either is to the ling. Similarly, the herring and pilchard are more like one another than either is to the anchovy, but all three are placed in one family, called the herring family.

We have now to take a survey of the principal kinds of fish in the divisions which have been defined above, and to notice the chief peculiarities by which they are distinguished from one another.

Our common dog-fishes on the one hand, and skates and rays on the other, represent the two distinct types which are found in the gristly or cartilaginous fishes. Dog-fishes and sharks all belong to one great type or division, the term dog-fishes being applied merely to the smaller and commoner kinds. A great many kinds occur on our coasts, but none of them are of any considerable commercial value, although some are in certain districts eaten as food or salted for use as bait. One of the commonest is the spiny dog-fish, often called the spur-dog, or picked dog-fish (Fig. 4). It has a strong sharp spine in front of each of the two dorsal fins, and has no ventral fin. It is a strong active swimmer which roams about in shoals pursuing and preying upon smaller bony fishes such as herring and pilchard. It is often very troublesome to drift-net fishermen on account of the damage it does to their nets. The Greenland shark, which has been frequently taken off our more northern coasts, resembles the spur-dog in having no ventral fin, but it has no spines connected with the dorsal fins. Its usual length is from eleven to fourteen feet. The spotted dog-fishes are very common, and as they live on and near the bottom are usually taken in the trawl. There are two kinds, the larger with large spots, the smaller with more numerous small spots. In these species

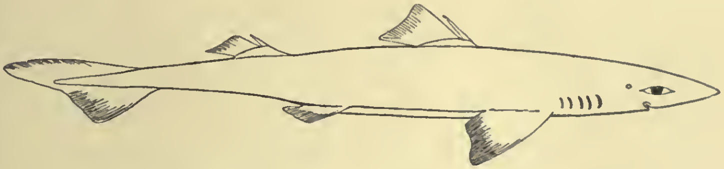


FIG. 4.—The Spiny Dog-fish, or Spur-dog.

the two dorsal fins are placed far back and rather close together, the ventral fin being opposite to the interval between them. The teeth are small, numerous, and pointed.

Two other common dog-fishes are the tope and the smooth-hound. They belong to the same family, in the members of which the dorsal fins are far apart, and the ventral is opposite the second dorsal. In the tope the teeth are large and sharp, in the smooth-hound they are small and flat or pavement-like. Both are often taken in the trawl, and reach a length of four or five feet. The blue shark is a long slender fish, similar to the dog-fishes just mentioned. It is said to grow to twenty-five feet in length, but only young specimens six or eight feet long are usually taken in British waters. These are not uncommonly caught in drift-nets off the Cornish coasts.

The porbeagle, the thrasher or fox-shark, and the basking shark, are three kinds of large but comparatively inoffensive sharks which occur frequently in British waters. With respect to their bodily peculiarities they all belong to one family, having a stout thick form with the second dorsal fin and the ventral fin of small size and opposite to one another. The porbeagle, which is frequently taken in summer by the Cornish fishermen, has long pointed teeth, and a keel on each side of its tail. Its length is from three to eight feet. The thrasher is conspicuously distinguished by the extraordinary length of the upper lobe of the tail, which is as long as the rest of the body. This tail is said to be used for beating whales, but it is certain that this shark feeds upon herrings, mackerel, and other gregarious fishes, and it seems probable that it swims round a shoal of these fishes and lashes about with its tail in order to keep them crowded together and prevent them from escaping. The basking shark is of very large size, reaching twenty-five to thirty feet in length. Its snout ends in a peculiar cylindrical projection. Its teeth are small and conical, and it has numerous long projections on its gill-bars which form a straining apparatus. These projections are called gill-rakers, and resemble those of the herring and other bony fishes, serving, as in these fishes, to strain from the water that is passed through the gill openings the multitudes of minute crustacea and other creatures which it contains. This large shark therefore, like the huge whale and the small herring, is nourished entirely by extremely minute forms of life. It visits the west coast of Ireland annually in considerable numbers, and is regularly hunted for the sake of the oil obtained from its liver. It has the habit of lying motionless at the surface of the sea, and as it is not easily alarmed the fishermen approach it in a boat and harpoon it. The fishery is chiefly practised off the Achill and Boffin Islands.

The peculiar form of skates and rays as compared with dog-fishes is connected with their habit of resting continually and concealing themselves on sandy or gravelly ground. In this respect they differ from dog-fishes as flat-fishes such as plaice and turbot differ from round fishes such as cod or haddock. But the mode of flattening in the two cases is as different as it possibly could be, the difference being that the lower surface in the skate is the belly, in the flat-fish the left or right side. Accordingly, if the skate is divided down the middle line of the upper surface the two halves will be exactly similar, whereas if the same thing is done to the plaice or turbot the one half will be the back of the fish and contain the brain, the other will be the belly half and contain the gills and intestines. The great breadth of the skates and rays is due to the enormous size of the breast fins, which extend from the hinder fins nearly to the tip of the snout, passing above the gill-openings, and it is from this cause that the gill-openings are on the lower surface of the fish. The tail is correspondingly reduced, forming a whip-like appendage on which the two small dorsal fins are placed.

Skates and rays are coast fishes, not occurring at depths beyond 500 fathoms, and they occur in greater or less abundance in all parts of the world: in the large rivers of tropical regions many kinds live entirely in fresh water.

The monk-fish or angel-fish, which is not uncommon in the English Channel and North Sea, although usually classed in the dog-fish division, shows us as it were the skate in process of manufacture. The body is flat, the breast fins large, and the fish rests on the ground, but the breast fins do not extend forwards to the head and do not entirely cover the gill-slits above; the hinder fins are not very much smaller than the breast fins, and there is no sudden decrease of size between the body and tail.

Of skates and rays there are several families, the principal being the electric rays, the common skates and rays, and two families of sting-rays. All these are represented in British waters. One kind of electric ray or torpedo reaching four feet in length is often taken in trawls on the south coast and in the North Sea. In the electric rays the front edge of the body is quite straight. In the sting-rays, commoner off the south coast than elsewhere, there are no fins on the tail, which is long and cord-like, but a strong spine with toothed edges projects from its dorsal side not far from the base.

The commoner rays, which are largely used as food, consist of several kinds in two groups, the long-snouted kinds and the short-snouted. The former are always distinguished as skates by fishermen, the latter as rays or roker. The common skate (Fig. 5) is distinguished by having a smooth skin and having the lower surface coloured a bluish-grey nearly all over. The flapper skate is rough on the back, and white beneath; the white skate and the long-nosed skate are two other large and common species. Of the rays the commonest is the thornback (Fig. 6), which has spines of various sizes all over its skin: in the starry ray the spines are all large and of nearly the same size; the cuckoo ray has a circular black mark with yellow lines in its centre, on each wing. Other species are also distinguished by similar small differences.

Among the bony fishes one division or order is characterised by the following peculiarities: the air-bladder when present, instead of being completely closed and separate from other cavities in the body, is connected by an opening or open tube

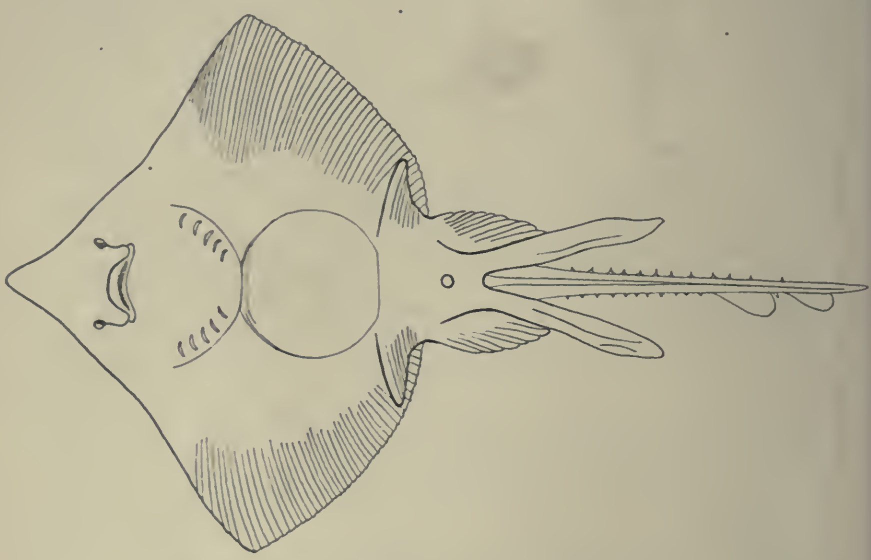


FIG. 5.—The Common Skate, lower or ventral surface.

with the interior of the gullet or stomach; the pelvic fins are either absent, as in eels, or are in their original position in the hinder part of the body, as for example in the salmon; thirdly, the fin-rays are soft and branched, that is to say each ray is composed lengthwise of a series of short pieces of bone united by flexible gristle or cartilage, and also divides towards its outer end into a number of separate smaller branches lying not in a tuft like a brush, but side by side like the ribs of a fan. In certain species however the first ray of the dorsal and ventral fins and of the breast-fins forms a strong undivided spine.

A great many of the fishes belonging to this division are inhabitants of fresh water, and our commonest fresh-water fishes belong to one family, the carp family. Many of the species pass certain periods of their lives in fresh water, and at other periods live in the sea. Some of these, like the salmon, ascend rivers in order to spawn, and descend after spawning: these are said to be anadromous, or ascending. Others, like the eel, live in rivers or ponds all their lives except when about to spawn, and then migrate to the sea: these are said to be katadromous, or

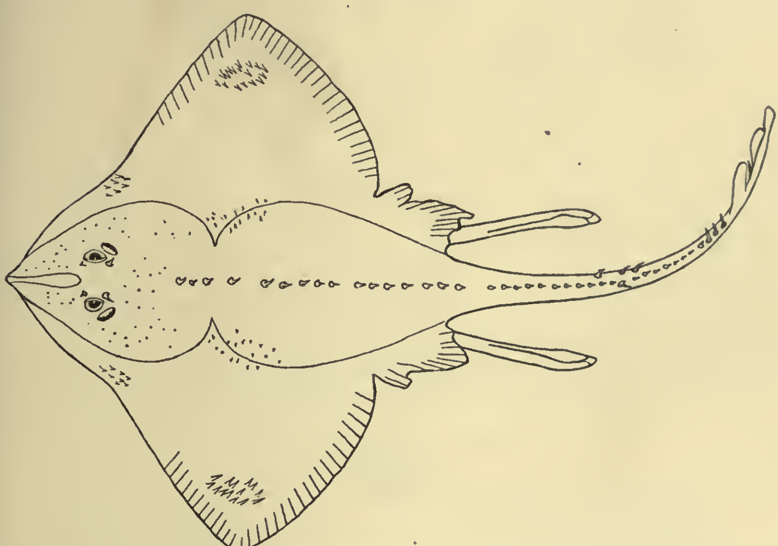


FIG. 6.—The Thornback, dorsal surface.

descending. Excluding the species which belong entirely to fresh water, there are only four families in British waters which are of any commercial importance, namely, the herring family, the salmon family, the eel family, and the gar-fish family.

The fishes of the herring family (Fig. 7) have a single dorsal fin of no great extent, situated near the middle of the back, and a single ventral fin near the tail. The tail-fin is deeply forked. It is a remarkable peculiarity in these fishes that the lateral line is absent. The body is rather narrow from side to side, and the lower edge is usually sharp and toothed like a saw. This family includes the herring, sprat, pilchard, shads, and the anchovy. The herring and sprat regularly enter estuaries, while the shads ascend to the upper waters of rivers and there spawn. The pilchard, on the other hand, is more completely marine. The herring is a northern fish, and does not occur in the Mediterranean, but is abundant on the American side of the Atlantic.

FIG. 7.—The Herring.

On the American coast there are also other abundant and valuable species of the herring family, namely the menhaden or moss-banker, which is much larger than the herring, and is valued chiefly for the oil which it yields and for use as bait, and the mattowocca, which ascends into fresh water in spring and spawns in ponds and lakes. The British shads are absent on the

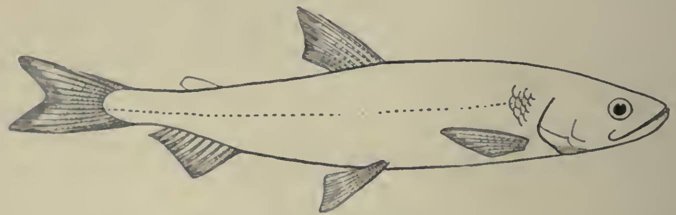


FIG. 8.—The Smelt.

American side, their place being taken by the American shad, a different species which is a much-valued article of food. The pilchard extends from the Mediterranean to the south-west coast of England, but not to the west side of the Atlantic. The anchovy is also a Mediterranean fish, but not American.

The fishes of the salmon family (Fig. 8) are distinguished by the possession of a rudimentary second dorsal fin : this fin, which is placed in the hinder part of the body, is small and destitute of fin-rays, consisting therefore only of skin and flesh. The tail-fin is less forked than in the herring family ; the lateral line and scales are well developed. The family includes fresh-water species, marine species, and species which like the salmon pass regularly from river to sea and sea to river. The fresh-water forms are the trout, the grayling, and the various kinds of char. Many kinds of sea trout have been distinguished in different parts of the British Islands, but in the opinion of the late Dr. Francis Day they are connected by intermediate forms with one another and with the fresh-water trout, and so constitute with the

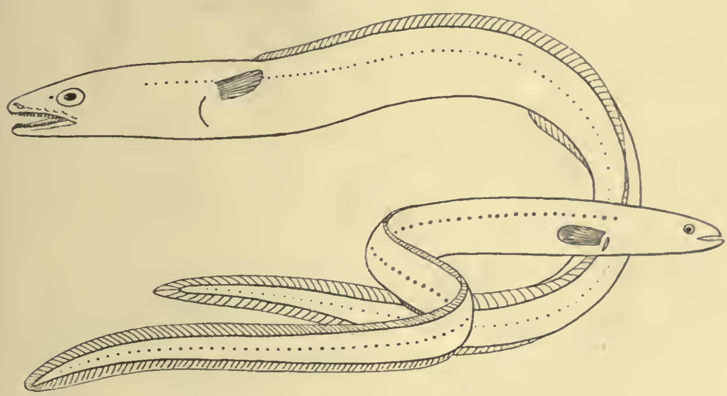


FIG. 9.—The Conger. FIG. 10.—The Common Eel.

latter one variable species. The smelt (Fig. 8) is found only in estuaries or near the mouths of rivers, and spawns in brackish water. It is distinguished by its somewhat transparent skin, which is bluish on the back, with a bright silvery band along each side. There are a few species of the salmon family which are entirely marine and live at considerable or even extreme depths in the sea or ocean. One of these marine forms, namely the argentine, is British, having been frequently taken off the west coast of Ireland and Scotland. It is distinguished by the smallness of its mouth, absence of teeth, and the shape of the body, which consists of flat surfaces bounded by longitudinal ridges. The argentine is of no commercial importance in this country.

The eel-like fishes (Figs. 9, 10) are distinguished by their well-known cylindrical, elongated form, by the entire absence of the pelvic fins, and by the continuous dorsal and ventral fins, which are not separated from the tail-fin. The scales are either entirely wanting, or small and completely buried in the skin as in the common eel. The latter and the conger are the only two British species. The eel is taken principally in fresh water, but it is known to migrate to the sea before spawning. The conger lives entirely in the sea: it is easily distinguished from the eel by its much larger eyes and jaws, and by the fact that its dorsal fin commences at a point much nearer the head than in the eel.

FIG. 11.

FIG. 12.

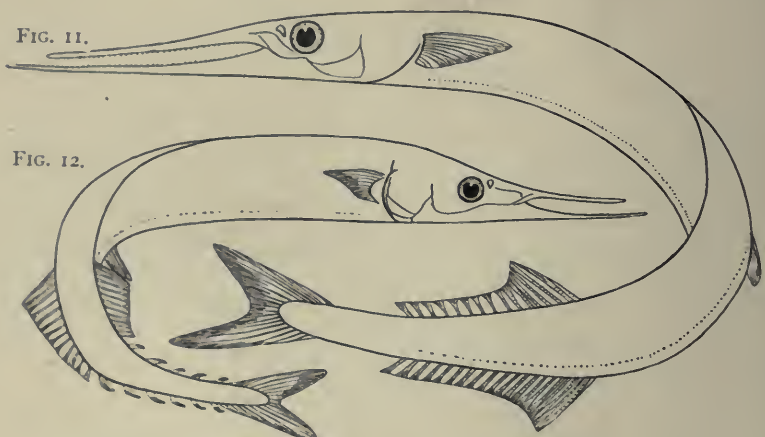


FIG. 11.—The Gar-pike, Guard-fish, or Long Nose.

FIG. 12.—The Saury-pike, or Skipper.

In the gar-pike family (Figs. 11, 12) there is but one dorsal fin, which consists of a rather small number of rays, and is placed opposite the ventral in the hinder part of the body near the tail. The air-bladder has no opening. In the gar-pike or guard-fish, and in the saury-pike, the jaws are elongated into a slender beak, the lower jaw being the longer. The saury-pike or skipper is distinguished by the presence of several small finlets behind both the dorsal and ventral fins. In both the body is slender and long. These fishes swim actively in shoals, and belong to the surface waters of the open ocean. They often occur off our coast in abundance in summer and autumn, and are taken in the mackerel nets: the gar-fish is much the commoner. The flying-fishes of the tropical parts of the ocean are placed in the same family, but in them the body is shorter and the jaws are not elongated. Their pectoral fins are greatly enlarged.

The next division of bony fishes is distinguished by the fact that the air-bladder is closed, the second pair of side fins is placed either just below or in front of the breast fins, and that all the fin-rays are jointed and flexible, or soft. They are pre-eminently the spineless fishes. The absence of spiny fin-rays is also associated with the almost entire absence of large spines on the body or head. The scales, however, are often well developed and furnished with a spiny border. This order is formed principally by the two great families of the cod-like fishes and the flat-fishes, by far the most important ground fishes, from a commercial point of view, in existence.

In the cod family (Fig. 13), there are in some cases three

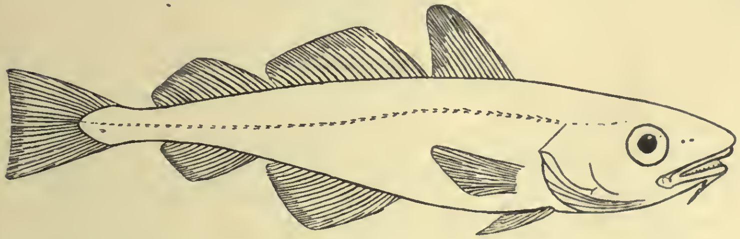


FIG. 13.—The Cod.

fins on the back and two behind the vent, in other species two on the back, the front one being short and the hinder long, and a long ventral, in other species again a single long dorsal and a single long ventral. The scales are small, without spines, and easily detached. There is in many kinds a barbel on the chin. These fishes belong chiefly to arctic and temperate coasts, a few species living in the ocean abysses. The more valuable British species are the cod, haddock, whiting, coalfish, pollack, bib or whiting pout, ling, hake, and tusk or torsk. The family of sand-eels is not very different in characters, but the fishes are much smaller:

they have the throat fins rudimentary or absent, and a single long dorsal and ventral. They burrow in the sand near shore. They occur on the coasts of Europe and America, and there are two British kinds, the larger sand-eel and the smaller.

The flat-fishes (Fig. 14) are the most remarkable of all fishes in structure, because the surface on which they lie on the

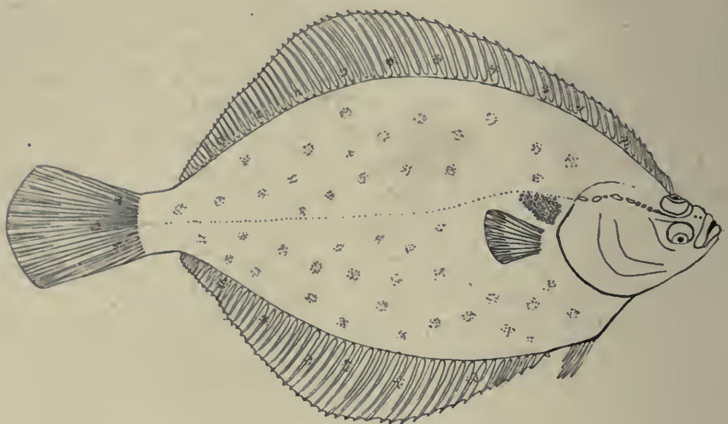


FIG. 14.—The Plaice.

ground is one side of the body, either the right or the left according to the species, and both eyes are on the upper side: the upper side also is coloured, the lower side white and without pigment. There is a long dorsal and long ventral extending nearly from head to tail. No flat-fishes are found in the great depths of oceans, but they are abundant in the tropics, and along all coasts except those of the extreme north and south. The tropical kinds are different from those of temperate regions, and are for the most part useless as food. The principal species in British waters are the plaice, flounder, dab, witch, lemon dab (called usually lemon sole), halibut, long rough dab, sole, turbot, brill, and megrim.

The third great division of the bony fishes has, like the second, a closed air-bladder and the pelvic fins in the front part of the body, but many of the fin rays form strong stiff spines, and spines are often largely developed on the head and body. This division contains a great variety of forms, classed by naturalists in a large number of families. The well-known fresh-water perch and a number of species resembling it form one family. In the perch and others there are two fins on the back, the front one being supported entirely by spines. In all fishes of this division when there are separate fins on the back the first always contains spiny rays only, while most of the rays in the rest are jointed and soft. In the perch-like fishes there are no scales over the longitudinal fins, no barbels, and the teeth are small and pointed. There are a great number of different kinds of fishes in the family, some of which live in fresh water and others in the sea. The latter are all coast fishes, and occur all over the world in temperate regions and the tropics. The only marine species of any great importance in Britain is the bass (Fig. 3), sometimes called salmon-bass on account of its elongated shape and bright silvery skin. It has no close relationship with the salmon, as is at once evident from its spiny first dorsal fin and the situation of its second pair of side fins beneath the breast fins.

The sea breams (Fig. 15) resemble many species of the perch

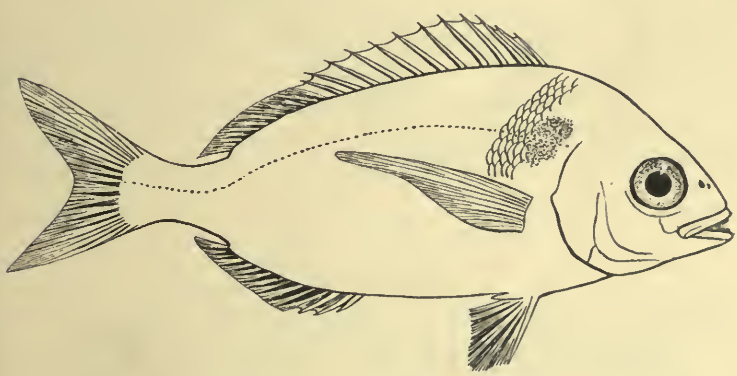


FIG. 15.—The Common Sea Bream.

family in the character and arrangement of their fins, but are distinguished by their peculiar teeth, of which those in front have broad cutting edges and those behind round tops formed for crushing. They are all coast fishes, and many different kinds occur more or less commonly on the more southern shores of the British Isles, but only one, the common sea bream, is of much importance in the market. They are bottom-feeding fishes, good, but not very rapid, swimmers.

The red mullet are well-known fishes, having always

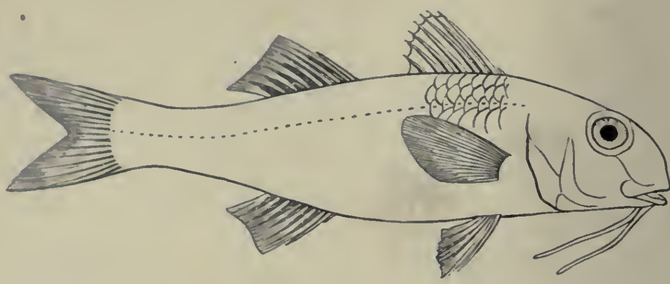


FIG. 16.—The Striped Red Mullet.

possessed a high reputation as delicacies for the table. They are distinguished by their red colour, the sloping front of the head, and the two stiff barbels attached to the chin (Fig. 16). They are bottom-feeders, and swim in shoals making long migrations. All the species of the family are marine, and none occur either at the surface or the bottom in mid-ocean. They belong to southern regions, and our red mullet only occurs abundantly on our more southern shores. The family of horse mackerels (Fig. 17) are chiefly distinguished by the great length

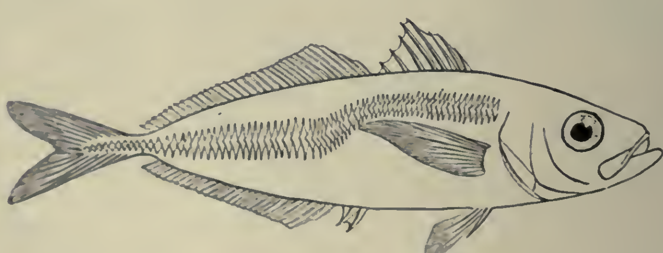


FIG. 17.—The Common Scad, or Horse Mackerel.

of the second dorsal fin, and the reduction of the first, which is in many quite rudimentary. They are for the most part oceanic fishes, and have their headquarters in the tropics. The well-known pilot-fish, celebrated as the companion and guide of the shark, belongs to this family, as also the common scad or horse mackerel.

The John dory (Fig. 18) and the boar-fish are the British members of a small family represented on the coasts of temperate regions. They have a thin, deep, short body, with a long first dorsal fin, and narrow second dorsal and ventral. The

FIG. 18.—The John dory.

mouth is curiously constructed, so that when opened it is automatically protruded and forms a tube of some length. They are very slow swimmers, accustomed to hover in the water, and swim both near the bottom and in mid-water: but the dory is chiefly taken by the trawl.

The mackerel family (Fig. 19) are much more like the horse mackerel than are the dory and boar-fish. They are active, powerful swimmers, and many of the species are large fish living in the open ocean: the latter are the tunnies. These fishes usually have two dorsal fins, and behind the second dorsal and ventral are a number of small finlets. The scales are small and in the tunnies are limited to certain regions on the breast, form-

FIG. 19.—The Mackerel.

ing a kind of corselet or breast-plate. They swim in shoals near the surface.

The angler or fishing frog (Fig. 20), sometimes called the monk-fish, belongs to a curious family of fishes in which the tail is much reduced, the mouth proportionately large, and the side fins formed for walking on the bottom or holding on to sea-weed. The angler lives on sandy or gravelly ground. The weevers are

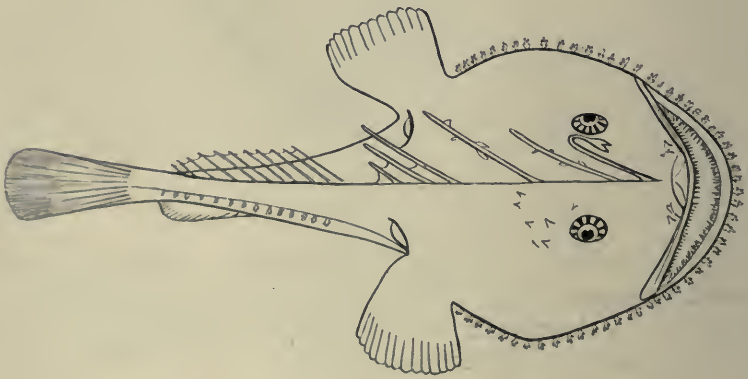


FIG. 20.—The Angler, Fishing Frog, or Monk-fish.

fishes of no value as food, which have their eyes on the top of the head and bury themselves in sand in an upright position. The bull heads or hard heads and the gurnards are usually placed in one family. They are bottom fishes. There are two dorsal fins, and long spines projecting from the bones of the gill-cover. In the bull heads, one of which is the common fresh-water miller's thumb, the skin is without scales and soft. The gurnards (Fig.

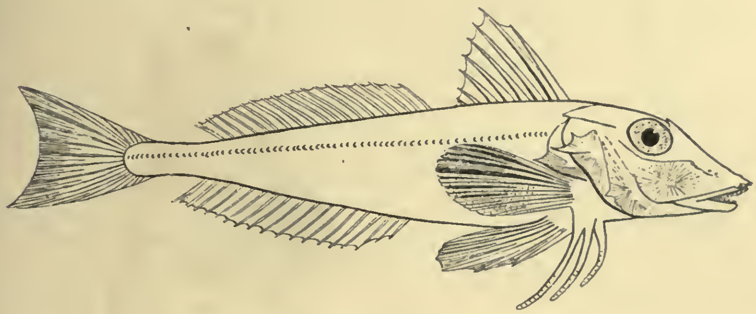


FIG. 21.—The Common or Grey Gurnard.

21) are distinguished by their three fingers or legs on each side of the body, and the bony covering of the head. In the sucker fishes and gobies the throat fins are formed into a sucker, which in the latter shows the original structure of the fins less altered

FIG. 22.—The Lump-sucker.

than in the former, where the sucker is level with the skin. These are all small shore fishes, except the lump-sucker (Fig. 22), which is of no importance as a food fish. The dragonet, the male of which (Fig. 23) is remarkable for its beautiful colouring of orange and blue, is allied to the gobies. There is another family of small sucker fishes, in which the sucker is not formed from the ventral fins, but lies between them ; they have a single dorsal fin without spines.

The blennies are shore fishes, mostly of small size, distinguished by their usually scaleless skin, and long dorsal and

FIG. 23.—The Dragonet, male.

ventral fins ; the body is long and the head blunt. The cat-fish (Fig. 24) is a gigantic blenny of northern seas living in deeper water.

Two other families it is necessary to mention are the atherines and grey mullets (Fig. 25), which are somewhat similar to one another. They are remarkable for having the second pair of

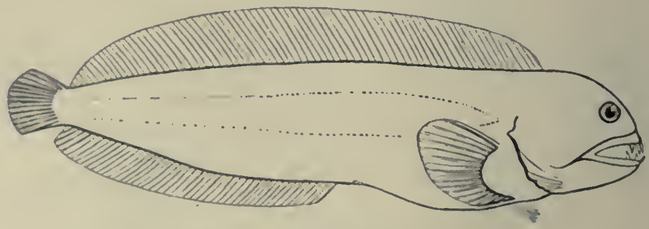


FIG. 24.—The Cat-fish.

side fins somewhat behind the breast fins. There are two dorsal fins, both short. The teeth are feeble in the atherines, absent in the grey mullets. The atherine or sand-smelt of the south shores of England resembles the true smelt in appearance and habits, and has a bright silvery band down the side.

In the stickleback family also the second pair of side fins are behind the breast fins, and the first dorsal is only represented by separate spines : there are no scales but bony plates. Only

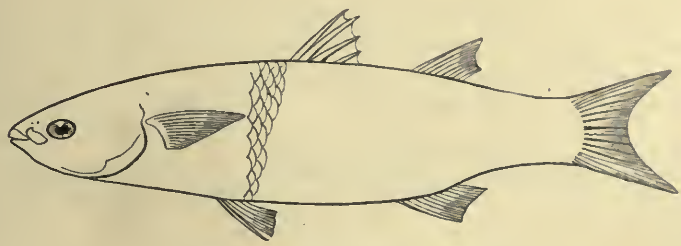


FIG. 25.—The Thick-lipped Grey Mullet.

one species lives in the sea, namely the fifteen-spined stickleback (Fig. 26).

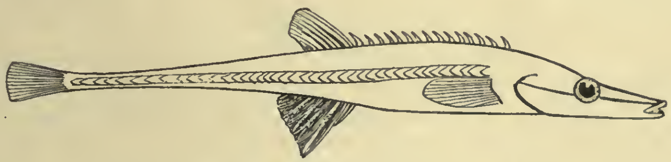


FIG. 26.—The Fifteen-spined or Sea Stickleback.

The wrasses are distinguished by possessing an extended dorsal fin the greater part of which is spinous, by having strong

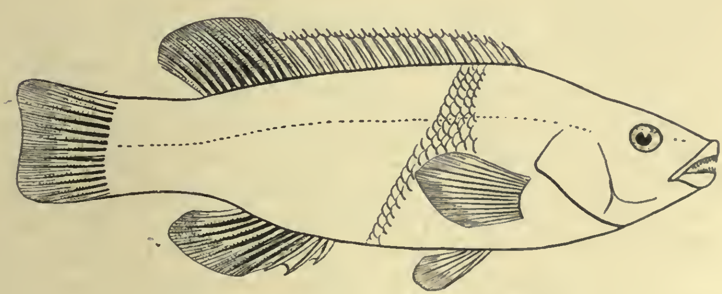


FIG. 27.—The Common or Ballan Wrasse.

crushing teeth in the throat, and thick fleshy lips over the jaws (Fig. 27). They are shore fishes which live in the neighbourhood of weed-covered rocks, and, in the tropical seas, of coral reefs. Most of them are gaudily or beautifully coloured, and though eatable are of no commercial importance in our country.

The pipe-fishes (Fig. 28) belong to another, that is a fourth, great division of the bony fishes, differing from the others in the structure of the gills and in many other respects. There are no

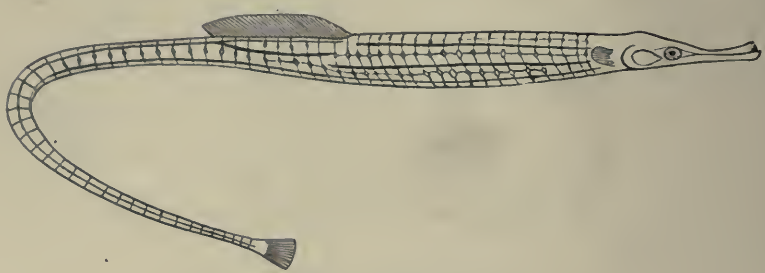


FIG. 28.—The Common Pipe-fish.

spiny fin-rays, a single thin soft dorsal fin, no second pair of side fins, and the tail fin much reduced or absent. The jaws are elongated into a tube with a small mouth at the end of it. These fishes live amongst sea-weeds, where by their swaying slow movements and similar colouring they are almost completely concealed. The sea-horse is one of them, and it is occasionally but rarely found on British or Irish coasts, but is common in the Channel Islands.

If we consider the different habits of the fishes just passed in review, and the various modes by which they are captured, we find the principal division is into bottom fishes and surface fishes; the bottom fishes can be again divided into hook fishes and trawl fishes, according to the instrument with which they are usually captured, but the division is not complete, many kinds being caught in both ways. The bottom fishes which are important in connection with national food supplies, are those which live in shallow or moderately deep water. The limit of profitable fishing is seldom much beyond two hundred fathoms, at which the deep sea region may be considered to commence, and the limit of beam trawling is much less than this and may be put at eighty fathoms. For commercial purposes therefore the fishes of the deep sea are of no value. With respect to abundance of supply and usefulness and palatability as part of a regular diet two families of bottom fishes surpass all the rest: these are the cod family and the flat-fish family. These families are developed more in the north temperate region than in any other part of the world. Moreover there is no region in the world in which within the north temperate region there is such a vast extent of fishing grounds less than eighty fathoms in depth, or less than two hundred fathoms, as in the neighbourhood of the British Islands. It may be safely said that there is no place in the world from which such a valuable and constant supply of fresh sea-fish is brought to market as from the North Sea. On the east coast of America the suitable ground is so limited, and the produce of such fishing of so little value, that the beam-trawl is not used at all, the name trawl being applied by American fishermen to the long-line. On that coast neither the sole nor the turbot are found, and the other flat-fishes representing plaice and lemon-soles are not equal to these in value.

In the beam-trawl fishery of Britain the principal products are haddock, plaice, soles, turbot, and brill, although a good many cod, hake, and ling are caught; whiting also are of some importance. Other families which contribute to the produce are skates and rays, gurnards, sea breams, and red mullet, also the angler and cat-fish, and to a certain extent the conger. In the line fishing the larger fish and those living in rather deeper water are taken, namely cod, ling, halibut, turbot, and brill, but plaice and soles to an insignificant extent; skate are also taken.

Of the surface fishes caught in drift-net and seine the great majority belong to the herring family, namely, herrings, pilchards, and sprats. The gar-fish and saury-pike are of no great importance, being taken only occasionally for a brief season, and not affording a large or continued supply. The mackerel, belonging to quite a different order of fishes, is the only other species of surface fish of great commercial importance.

We may next consider the particular geographical limits of the more important species within the seas surrounding the British Islands. These seas may be said to form an area of transition between the home of the southern or Mediterranean species and that of the northern or Arctic forms. Thus the plaice, cod, and herring are more numerous and of finer quality in the more northern parts of our seas; the sole, pilchard, John dory, conger, and various others are characteristic of the southern coasts of Britain and Ireland. Soles are scarce north of a line drawn from St. Abb's Head to the northern extremity of Denmark. Halibut are scarce even in the northern part of the North Sea, and only become plentiful as the Faröe Islands are approached. Turbot and brill are southern forms like the sole, but extend somewhat further to the north. Speaking generally, the majority of the cod family belong to the north, the hake being the most southern, while of flat-fishes the forms most similar to the plaice and halibut are northern, the rest southern. On the south coasts families such as the mullets, breams, and gurnards are abundant, which are scarce or absent in the north.

The various kinds differ also considerably in the depth of water and distance from shore at which they live, and the depth of water seems to be by far the more important of these two conditions in separating the territories or ranges of different fishes. Among the flat-fishes the species which lives nearest to the land is the flounder, which is found chiefly in estuaries and the lower parts of rivers, often ascending to fresh water, and only going to sea to spawn, where it is not found beyond a depth of thirty fathoms. Plaice is next in attachment to the shore, being seldom taken on grounds more than forty fathoms deep, and most abundant at from five fathoms to thirty; it enters estuaries also, but does not ascend so high as the flounder. The common dab becomes rare beyond thirty-five fathoms, and like the plaice is abundant in shallow water and in estuaries. The sole, like the plaice, is often fairly abundant in shallow water, and enters estuaries; it is not found plentifully beyond forty fathoms. The lemon dab has much the same limits as the sole, but is not so common in shallow water near shore. The brill and turbot have about the same limits as the sole, and are often taken in quite shallow water, though seldom entering estuaries. The long rough dab occurs at from twenty to fifty fathoms, and the megrim and witch are deep-water species extending from twenty or thirty fathoms to three hundred fathoms and seven hundred fathoms respectively.

Among round fishes cod and haddock range from ten fathoms to one hundred or one hundred and fifty, but adult whiting are seldom taken in less than ten or more than forty fathoms. Ling belong to deep water, ranging from ten to one hundred and fifty fathoms or more. Pollack haunt the neighbourhood of weed-covered rocks; coal-fish range from five to seventy fathoms or more. Gurnard extend from five to eighty fathoms, and the John dory from five to forty.

CHAPTER III

THE GENERATION OF FISHES AND THEIR FECUNDITY

THE generative organs of fishes differ considerably in different classes and orders. In skates and dog-fishes (Fig. 29) they resemble closely those of birds. In the female the ovary, or organ where the eggs are produced, is a lobed mass at each side of the body cavity, and attached to the dorsal wall of that cavity. The eggs when mature are very large, and in adult specimens a number of them of various sizes and stages of development are seen bulging out from the surface of the ovary. These eggs when ripe burst through the surface and become free. They are round balls of yellow yolk, of considerable size, larger in some species than in others, but not very much larger or smaller than the yolk of a hen's egg. Running along the back of the abdominal cavity is a fleshy tube, the egg-tube or oviduct. This tube is open at both ends. Inside the body its open front end is situated at the side of the gullet in front of the liver. Its hinder end leads into a sac which opens to the exterior at the vent. The eggs must get into this tube, and pass down it, before they can escape from the fish. They are taken up into the opening at its front end, swallowed as it were by the egg-tube, and pressed down it by the movement of its sides. Towards the upper part of this tube is a ring-like thickening, and here the tough horny shell is formed. The upper end of the oviduct usually contains some of the milt of the male, introduced during the union of the sexes, which takes place from time to time as in higher animals. By the action of this milt the germ in the yolk is fertilised. At the same time a certain quantity of clear sticky liquid, the "white," is exuded from the sides of the egg-tube and surrounds the yolk. The lower part of the egg-shell is formed before the descent of the ball of yolk, and stops up the passage of the egg-tube so that the yolk rests within it until the remainder of the shell is formed.

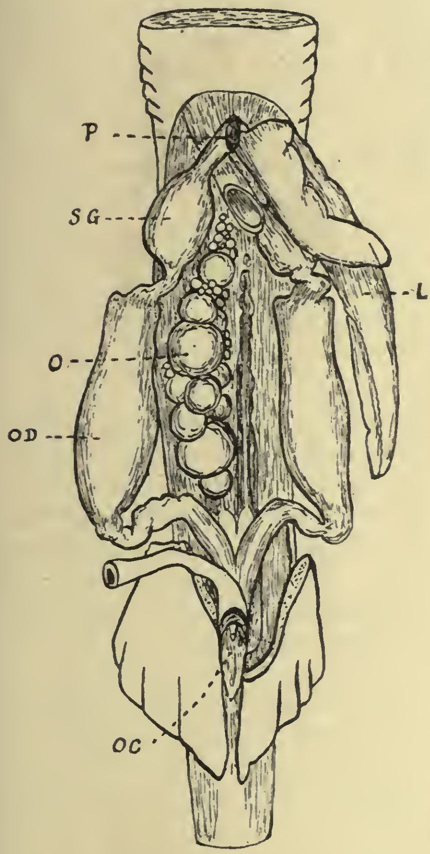


FIG. 29.—Diagram of a dissection of a female of the Smaller Spotted Dog-fish to show the ovary and oviducts. **O.** the right ovary, the only one present in the dog-fish ; **OD.** the oviduct, containing a ripe egg on its passage towards the exterior ; **SG.** the gland of the oviduct, or eggshell-gland ; **P.** the anterior apertures of the two oviducts ; **OC.** the posterior opening of the oviducts into the "cloaca," behind the opening of the intestine. (After Milnes Marshall.)

Then the shell, containing the white and the yolk, is separated from the sides of the oviduct and passes down to the end, where it is "laid," or driven out. In skates and the rough dog-fishes there are stiff rods or long tendrils at the four corners of the egg. These are of course formed with the shell : the lower projections are the first part of the shell formed, the upper the last.

In some dog-fishes, for instance the common spiny dog-fish, no eggs are laid, but the young are born alive. In this case a shell of the usual kind is not formed in the egg-tube, neither is a shell altogether absent. In a female opened before the development of the young has proceeded very far the lower part of each egg-tube is found to contain two or three yolks enclosed in a single thin transparent horny case, which corresponds to the egg-shell described above. But this egg-shell is not oblong with projections at the corners, but shaped like a cigar pointed at both ends. It is burst when the little fish are well developed. Thus the eggs in the spiny dog-fish develop inside the egg-tube, and when the young are born they are similar to their mother except in size, and are able to swim about actively and vigorously.

In the male dog-fish the generative organ consists of a flat solid mass attached to the back of the body cavity on each side of the intestine. It is similar in position to the ovary of the female, but the surface is smooth, not bulged out with eggs. This organ, the milt or testis, consists of a number of tubes, in which the liquid milt is produced. The milt or semen does not find its way to the exterior by a direct route, but by the aid of a portion of the kidney through which it passes. The tubes of the testis are in communication at the back of the body cavity with the tubes of the foremost part of the kidney, and the latter open into a single larger tube on each side, which like the egg-tube in the female passes down the body to open into the sac at the end of the intestine.

The male dog-fish or skate is distinguished, as is well known, by two long thick projections attached at each side of the vent, and connected with the hinder paired fins, of which they form the hinder part. During coition the male inserts these two organs through the vent of the female, into her two egg-tubes, and the milt is passed along them. In the males of skates and rays there is a patch of sharp-pointed spines on each wing, which is absent in the females, but whether these are used in the act of copulation or not is unknown.

The eggs of the common spotted dog-fishes (*Scyllium canicula* and *catulus*) are attached, when laid, to weeds or other objects standing up on the sea-bottom, by means of their tendrils, which are tightly wound round the support. The manner in which this is effected has been observed in the aquarium of the Plymouth Laboratory, for these species lay their eggs freely in captivity. The lower tendrils project first from the vent, and the female rubs herself against some fixed body, swimming round and round about it. The tendrils soon catch fast in some slight projection, and the egg is thus dragged out and firmly bound to the fixed object at the same time, and there it remains while development proceeds. The large rough dog-fish, or nurse-hound, lays its eggs in this way in some places among sea-weed not far from low-water mark, where at low tide they can be gathered by hand. Besides the two spotted species there is only one other occurring in British seas which lays eggs, namely, the black-mouthed dog-fish (*Pristiurus melanostoma*), and this species, which is abundant in the Mediterranean, has been very rarely taken off our coasts. The rest of the British sharks and dog-fishes produce their young alive. All the ordinary skates and rays, on the other hand, lay eggs which differ only in size and minor peculiarities in the different species. The electric ray (*Torpedo*), the eagle-ray (*Myliobatis*) and the sting-ray (*Trygon*) bring forth their young alive. There is no evidence at present to show that the egg-laying rays seek particular localities in which to deposit their eggs. The eggs are occasionally taken in the trawl or dredge, and the empty shells are often cast ashore. They are sometimes called mermaids' purses.

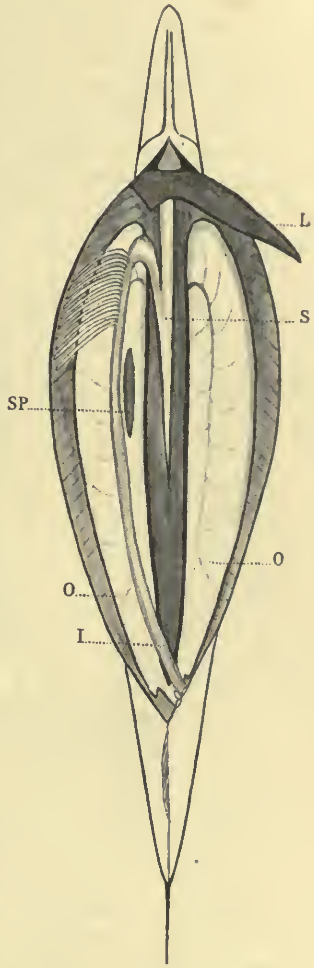


FIG. 30.—Diagram of a Herring with its body cavity laid open at the lower edge, to show the roes and intestines, &c. **L.** liver, in front of which is seen the heart; **S.** the stomach; **I.** the intestine; **SP.** the spleen; **O.** the roes or milts opening together behind the opening of the intestine.

In the majority of the bony fishes the condition of the roes and the mode in which the eggs are produced and fertilised are quite different. If we take the herring as an instance, it is well known that in this fish (Fig. 30) there is a hard roe or soft roe on each side of the body cavity, and that in the spawning season these are very large so that the abdomen of the fish is distended by them. The roe or hard roe occurs in the female fish and contains the eggs or spawn, the milt or soft roe belongs to the male and contains the white milky liquid which must act upon the eggs before they can develop. Careful examination shows that the roe, or hard roe as it is often called, the ovary as naturalists call it, is in the form of a sac, which is smooth on the outside and hollow inside. This sac has only one opening, the opening by which the spawn escapes, on the lower side of the fish, behind the vent. There is a roe on each side, and the two open at a common opening (Fig. 32). The inner wall of the sac is not smooth but thrown into a number of ridges running along the length of the sac. These ridges consist almost entirely of eggs, and together they correspond to the ovary of

FIG. 31.—Diagram of the interior structure of the soft roe or testis in the Herring.

FIG. 32.—Similar diagram of the hard roe or ovary of the same fish.

a dog-fish, a skate, or a hen. The great difference is that the single eggs are very much smaller, and very much more numerous. The eggs burst through the surface of the ridges on the inside of the roe, and so become free in its interior, and then they are squeezed out through the external opening into the water. Now it was mentioned above that the egg as it escaped from the ovary in the dog-fish consisted only of the round yellow yolk, surrounded by a thin delicate skin. The outer parts of the complete egg, the white and the shell, are added in the oviduct or egg-tube. In the herring the eggs which are set free from the ridges inside the roe are little round balls of yolk, of course containing a germ, and they are covered with a transparent membrane. These eggs are sent out into the water just as they are, and no "white" or shell is added to them. In fact, in all cases throughout the animal kingdom, the essential part of an egg is the germ, from which as from a centre the formation of the new creature commences. A greater or smaller quantity of yolk, which is the food of the germ, is connected with it, and yolk and germ are contained in a membrane or skin. If a number of hen's eggs were carefully broken, the yolks separated and placed in water, they would correspond exactly to the eggs of the herring or the salmon. The white and the shell are not primary and essential parts of the egg, though they are required under certain conditions. In the case of the frog there is no shell, but each yolk is surrounded in the egg-tube by a kind of "white" which swells up in water when the spawn is laid, and causes a number of the eggs to stick together in masses.

An egg which is surrounded by a strong tough shell must be fertilised before the shell is formed, and accordingly in dog-fishes and skates as in birds the sperms are introduced into the upper part of the egg-tube, where fertilisation takes place. But the eggs of bony fishes are shed into the water unfertilised; there is, properly speaking, no egg-tube, and with the exception of a few species no milt is introduced into the cavity of the roe. These eggs come into contact with the milt when they are expelled from the roe of the female into the water, and it is an interesting fact that there is a minute aperture or pore in the egg membrane for the admission of the sperm. This aperture, technically known as the *micropyle*, is represented in the diagrams Figs. 45–48, p. 95.

In the case of the dog-fish or skate the eggs are laid singly or in pairs at considerable intervals, as the formation of the shell occupies a considerable time, and only two yolks come from the ovary together. The period of egg-laying too extends over a considerable part of the year. The number of eggs laid in one season could be ascertained, but I do not know of any special inquiries on this point. On the other hand the period during which eggs or spawn are produced by the bony fishes is limited to a few months, and in the case of a single fish may last only a few days or weeks. The period is annual, and occurs at about the same time every year. The total annual crop is shed, and then for the rest of the year no more eggs are laid, but the formation of next season's crop goes on in the roe or ovary. The total number of eggs produced by a single fish is very large, and has been carefully investigated. The method by which this is done is as follows. All the eggs in the roe of a fish, such as a herring, before it has begun to spawn, will be shed in the spawning process, that is to say, all that are large enough to be distinguished without a microscope. The whole of the two roes are carefully weighed, and then a small quantity, say ½ oz., is weighed. Then this selected portion of the roe is gradually boiled, in order to separate the eggs and make them more distinct. The number in the selected portion is then counted carefully, and the result is multiplied by the number of times the weight of the selected portion is contained in the weight of the whole of the two roes. For example, suppose the two roes of a herring weigh 8 oz. or half a pound, and that ½ oz. contains 1,000 eggs; then the total number in the fish is 16,000. Dr. T. Wemyss Fulton published in 1890[1] the results of an extensive investigation of this kind. Some of his figures will be found in the table opposite.

It will be seen that in this list the ling is the most prolific and the herring the least, although the herring is a more abundant fish than the ling. This is not so surprising and contradictory as it appears, for the ling is a predaceous fish and very much larger than the herring, and a large predaceous fish must necessarily be less numerous than the smaller fishes on which it preys. Next to the ling in fecundity is the turbot, also a large predaceous fish, and next comes the cod. The turbot and plaice may be compared with similar results to those just mentioned in reference to the ling and the herring. The turbot is much less numerous than the plaice, although the latter produces a much smaller number of eggs from each individual fish.

Such facts as these, which very commonly come before us in the study of the conditions affecting the relative abundance of different animals, show that mere fecundity is by no means the most important condition. If every egg produced by a fish developed into an adult individual the increase in numbers would be very rapid

[1] "The Comparative Fecundity of Sea-Fishes," *Ninth Ann. Rep. Fishery Board for Scotland.*

indeed, so that in a very short time the multitudes of one species would be enough to fill the sea, to say nothing of a number of species together. As it is quite clear that fishes producing a few

Species.	Length.	Weight.	No. of Eggs.
Herring	11⅝ in.	...	30,000
,,	11⅞ in.	...	26,000
,,	11½ in.	...	47,000
,,	11 in.	...	21,000
Cod	37½ in.	23 lbs.	3,970,000
,,	38 in.	21½ lbs.	6,652,000
,,	35 in.	16 lbs.	2,963,000
Haddock	22 in.	4 lbs.	806,000
,,	27 in.	6½ lbs.	546,000
,,	18½ in.	2 lbs. 6 oz.	399,000
,,	16½ in.	1 lb. 7½ oz.	349,000
,,	16½ in.	1½ lbs.	156,000
Whiting	11½ in.	10½ oz.	109,000
,,	16½ in.	14½ oz.	131,000
Ling	61 in.	54 lbs.	28,361,000
,,	45 in.	25 lbs.	18,520,000
,,	45 in.	18½ lbs.	12,306,000
,,	62 in.	40 lbs.	14,525,000
Plaice	17½ in.	3 lbs. ¼ oz.	223,000
,,	17½ in.	2 lbs. 10 oz.	148,000
,,	22 in.	4 lbs. 3½ oz.	487,000
,,	22¼ in.	4 lbs. 11½ oz.	324,000
,,	20½ in.	3 lbs. 12½ oz.	323,000
Lemon or	15 in.	2½ lbs.	672,000
Merry Sole	12½ in.	15¼ oz.	150,000
Flounder	14¾ in	1 lb. 9½ oz.	1,638,000
,,	12¾ in.	13¾ oz	711,000
,,	10½ in.	12 oz. (nearly)	561,000
Dab	8½ in.	...	128,000
,,	7¼ in.	...	79,000
,,	8¼ in.	...	109,852
Sole	17½ in.	1 lb. 15¼ oz.	750,000
,,	18 in.	2 lbs. 5½ oz.	553,000
,,	16 in.	1 lb. 10 oz.	409,000
Turbot	28 in.	17 lbs. 5 oz.	9,161,000
,,	24 in.	14 lbs.	8,104,000
Mackerel	16 in.	1 lb. 8½ oz.	639,000
,,	16 in.	1 lb. 8¾ oz.	689,000
Grey Gurnard	12½ in.	9¾ oz.	192,000
,,	14 in.	12¾ oz.	244,000
,,	14½ in.	14 oz.	269,000
,,	13½ in.	13½ oz.	297,000
,,	15½ in.	19 oz.	278,000

thousand eggs are often more abundant, in spite of hosts of enemies, than those which produce millions, we learn that the production of a very large number of eggs usually implies an enormous destruction of eggs and young, either by the action of enemies or by surrounding conditions or from scarcity of the natural food. Thus in the case of the herring, which feeds both in the young and the adult state chiefly on the swarming minute creatures in the sea, an abundance of food is usually everywhere available, while only those young turbot or ling can survive which happen to find smaller fishes than themselves to feed upon, and their prey is not to be found in every part of the sea, so that a large proportion are starved to death. On the other hand if the number of the young of the predaceous fishes were smaller, then the chances of some of them finding prey would be fewer, and consequently the abundance of the species would diminish. Careful consideration shows that the production of large numbers of eggs and young leads to the same result as the protection and nourishment by the parents of a smaller number. There are plenty of instances in which on both systems the abundance of the adults neither increases nor diminishes greatly; for example, the spiny dog-fish which produces only six or seven young at a birth is as abundant as ling or turbot. The one system may be compared to the starting of a vast number of small boats of which only a small percentage escape the perils of the sea and reach port, the other to the equipment of a few large steamers which are nearly certain to accomplish their voyage safely and punctually.

The eggs of different fishes are of different sizes. Those of the trout and salmon are much larger than those of the most familiar sea-fishes, and partly in consequence of this, but chiefly because they are deposited in rivers and streams, they were well known to sportsmen and naturalists long before the buoyant eggs of sea-fishes were discovered. The egg of the salmon is about $\frac{1}{4}$ inch in diameter. One of the largest among the eggs of sea-fishes, namely that of the plaice, is only $\frac{1}{12}$ inch across, and the majority are little more than $\frac{1}{25}$ inch.

In the spawning season a certain proportion of the female fish captured are ripe, and when they are handled or gently squeezed the spawn escapes freely from them. The spawn if taken on the hand forms a transparent mass which is easily seen to be composed of a large number of round grains, similar in appearance to glass beads. When the roe is opened before the spawning season the eggs are seen to be minute white grains, looking somewhat like grains of chalk. If the roe of a spawning fish is examined it is seen that some of the eggs have become larger and transparent, while a portion of the roe still consists of the chalk-white smaller eggs. In fact, the eggs become more or less clear and transparent when they are ripe, and then they become loosened from the sides of the roe, fall into the cavity, and so make their way to the exterior.

The difference between the unripe and the ripe egg is due to a change in the condition of the yolk, which becomes more liquid and less granular. But there is a still earlier condition of the egg in which there is no yolk at all. In this condition the egg consists really of germ only, and is a minute mass of transparent living substance. The formation of the yolk commences some months before the spawning season, and the presence of opaque eggs in the roe, of eggs which have the appearance of separate grains to the naked eye, is a sure sign that the fish would have spawned in the following season. In small fish however, and in large fish some time after the spawning season, the roe is usually found to be quite small and, when cut open, to show no appearance of distinct grains. It appears soft and contains only the very young eggs in which no yolk has been formed. It is often said of fish in this condition that they have no roe in them, but the roe though small is always present, and accurate knowledge of the changes through which it passes is very necessary in considering the question of the age and size at which fish begin to breed.

The generative organs of the male fish are very different in structure from those of the female. In the herring and nearly all other bony fishes the male organ, milt as it is sometimes called, testis as naturalists call it, is a solid body. That is to say, it is not a sac with a large internal cavity like the roe, but when cut through appears to be a mass of substance without cavities, although of a soft nature and when ripe full of liquid. It is really composed of a number of tubes which join with one another like the tributaries of a river until a single tube is reached which opens to the exterior with that of the opposite side by a single aperture (Fig. 31). In consequence of the number of these tubes the testis has really a spongy structure, and the liquid milt is produced in the tubes, and pressed out at the external opening into the water in the spawning process. The milt mixes with the sea-water and there acts upon the eggs shed at the same time by the female, and so the eggs are fertilised.

The milt both in bony fishes and in skates and dog-fishes appears to be a thick white liquid. It really consists of innumerable minute solid particles suspended in a transparent liquid. These particles can only be distinguished with the help of the microscope. They are called spermatozoa, or, for the sake of brevity, sperms. The most remarkable fact about them is that when alive and fully developed or "ripe" they are in constant and active motion. Each consists of a thicker, denser portion, the head, to which is attached a very thin long lash or tail, and the motion is due to the incessant vibration of the tail from side to side, which drives the sperm rapidly through the liquid containing it, just as a tadpole is propelled through the water by the movement of its tail. The extraordinary activity of the multitude of sperms in a drop of living milt examined under the microscope is an interesting spectacle, and forcibly reminds the observer of a number of animalculæ in a drop of water. In fact, when first discovered the sperms were called the animalculæ of the semen, and the part they played in the fertilisation of the egg was not understood.

The head of the sperm differs in shape in different orders of fishes. In the skates and rays it is a long rod having a spiral form, in bony fishes generally it is nearly globular, but in the herring its length is somewhat greater than its breadth. Fig. 33 represents the shape of the sperms of certain fishes as seen when highly magnified. The side of each square in the figure represents $\frac{1}{1000}$ inch, so that the extremely minute size of the objects is plainly evident; the head of the sperm of the thornback ray is a little more than $\frac{2}{1000}$ inch in length, that of the herring about $\frac{1}{5000}$ inch, of the pike a little less, while in the plaice and sole the diameter of the head does not exceed $\frac{1}{10,000}$ inch.

Fertilisation consists in the entrance of one of these sperms into the egg, where its head unites with the germ, and the latter is then capable of development. It would be utterly out of the question to consider the number of these sperms in the milt of the male fish: it would be as easy to give the number of hairs in a good head of hair, or the number of grains in a ton of sand. But it is a curious fact that only one sperm is needed to effect the fertilisation of each egg, the great number are only advantageous in securing that every egg shall be fertilised.

In the herring the hard roe of the female and the soft roe of the male are both smooth outside, and both equally large. But although their connections and their mode of construction are essentially the same in other fishes their appearance and size are in many cases very different. In the flat fishes such as the plaice, sole, turbot, &c., the soft roe of the male is much smaller than the hard roe of the female. The latter has its opening in

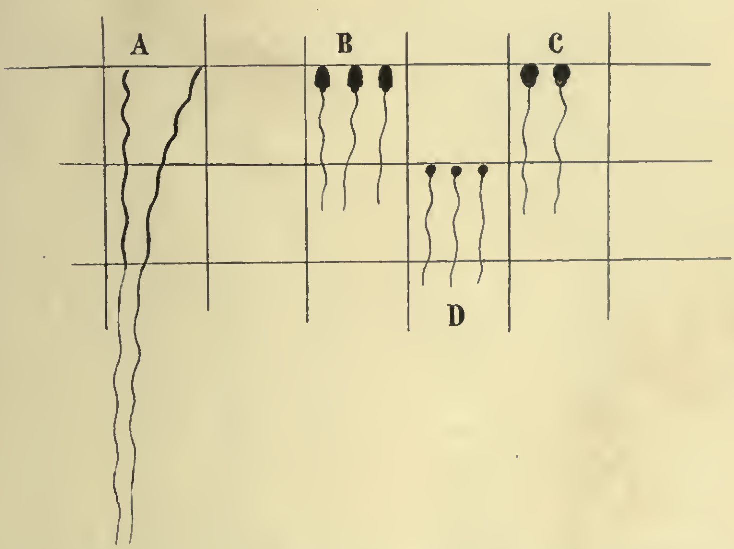


FIG. 33.—Sperms of various fishes, highly magnified. **A**, those of the Thornback Ray; **B**, of the Herring; **C**, of the Pike; **D**, of Plaice or Sole. Each side of the squares represents $\frac{1}{1000}$ inch.

front of the ventral fin, not far behind the head, and extends back on each side beneath the flesh of the body, nearly to the root of the tail. The soft roe, on the contrary, is a small white mass at the back of the central cavity of the fish. The difference in size between the male and female roes is greatest in the sole, and their appearance and position in this fish are clearly shewn in the four illustrations here given. Fig. 34 represents the appearance of the belly cavity of a female sole laid open by the removal of the skin and flesh covering that cavity on the upper side. The organs are seen in their natural position. L is the liver with the large globular gall-bladder attached to it. G is the gut or intestine, bent upon itself three times so as to lie in four lengths side by side. Behind the gut is seen the hinder part of the hard roe, R, the front part being covered and concealed beneath the gut. Fig. 35 shows what is seen when the gut and the liver are removed. Nearly the whole length of the roe is now visible, ending in front in a tube which joins another tube from the roe of the lower side of the fish to open on the edge of the body behind the head. The roe on each side rests against a series of bones lying in the middle region of the body.

When a male sole is cut open in a similar manner, as seen in Fig. 36, the intestine and the liver are seen as in the female, but no roe is visible. In fact until a few years ago a deal of mystery hung over the question of the male sole, and it was even doubtful to fishermen and others whether there were two sexes in the sole at all. The truth is that the soft roes of the sole are very small. Their size and position are shown in Fig. 37, representing the appearance of the belly cavity after the liver and intestines have been taken out. The soft roes or milts, indicated by the letter M, are small oval white bodies lying at the back of the central cavity, and connected with the edge of the body by two cords, in which the milt is conducted to the exterior. The external opening is on the upper side of the fish just behind the opening of the gut.

In the cod, haddock, and other fishes of the cod family the hard roes are short, thick bags, joined together at their hinder ends and placed at the back of the belly cavity. The soft roes have a very different appearance to that seen in the majority of fishes. They are white narrow frills, in a position corresponding to that of the ovaries. They consist of a pair of narrow thickened bands attached by thin membranes to the back of the cavity: they are very much longer than the attached edges of these membranes and consequently are thrown into zigzag folds.

Dr. Fulton has investigated, besides the comparative fecundity of the sea fishes, the proportions between the numbers and sizes of the two sexes. He did this by study of the records of the sizes and sexes of all the fish captured in the trawl of the investigation steamer of the Scotch Fishery Board, supplemented by the examination of numbers of certain kinds of fish captured in

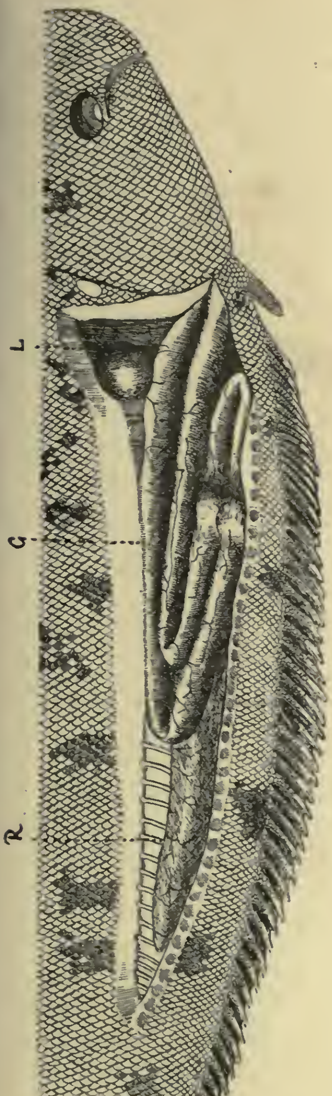


FIG. 34.—The abdomen of the female sole, laid open with the organs in their natural position. **R**, the hard roe; **G**, the gut; **L**, the liver with the gall-bladder.

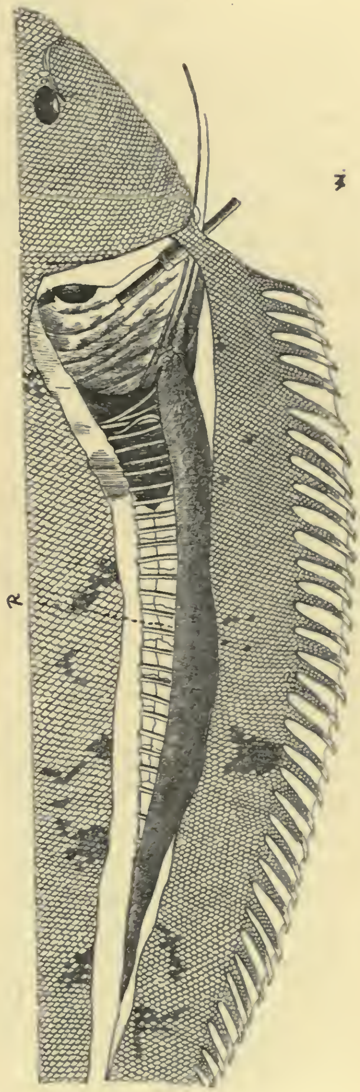


FIG. 35.—The same after removal of the liver and gut, the roe seen in its whole length.

other ways. The reliability of the results depends upon the question whether the means by which the fish were obtained collected all sizes and sexes equally and indifferently. A certain mode of fishing might capture fish only above or below a certain size ; in the case of the conger if hooks of large size were used only females would be taken by hook and line. But as the Board's steamer *Garland* fished with a small-meshed beam tawl, and on various grounds, and as large numbers of fish of all sizes were examined, we may justly consider Dr. Fulton's conclusions to be sound. The proportions are expressed by giving the number of females to every 100 males, and the average length of the females compared with the average length of males taken as 100.

	Number of females to 100 males.	Ratio of length of females to males at 100.
Cod	133	95
Haddock	188	98
Whiting	211	104
Bib	204	99
Plaice	142	114
Dab	295	103
Flounder	62	126
Lemon Sole	308	105
Witch	260	114
Brill	144	123
Turbot	198	118
Halibut	150	
Long Rough Dab	511	130
Grey Gurnard	409	108
Angler	26	87
Lump-sucker	25	166
Cat-fish	79	87
Herring	99	?

It is interesting to consider what is the meaning of this inferiority, in number and size, of the males in the majority of cases and of the difference between different species in these respects. The number of males is the same as the number of pairs of milts, but the size of the males is not necessarily in proportion to the size of the milts. It will simplify matters therefore to put aside for a time the question of the size of the male fish, and consider only the proportion of milts to roes in number and size. We have no reason to suppose that the provision made for the proper fertilisation of the eggs is insufficient, we may take it for granted therefore that in all cases the quantity of milt produced is enough to fertilise all the eggs. Mention has already been made of the great differences which exist in the size of the milts in proportion to the size of the male fish, and in proportion to the size of the roes in the female. An exact investigation of these differences has not yet been completely carried

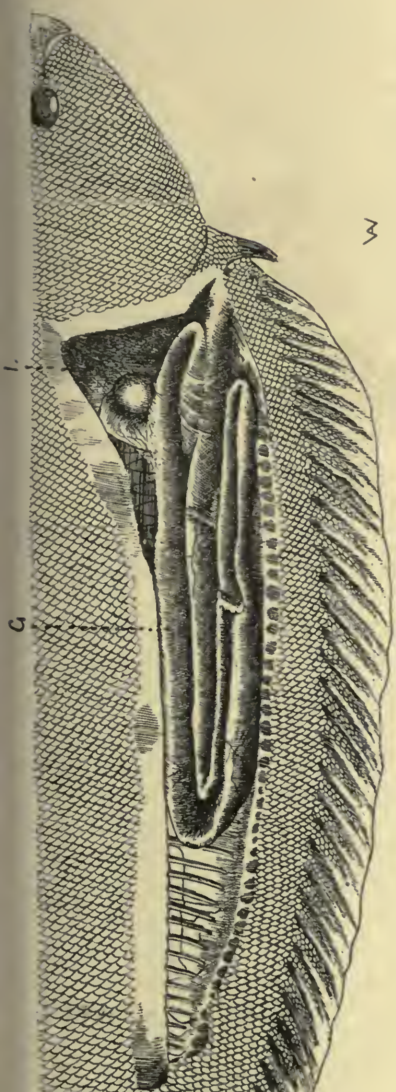


FIG. 36.—The abdomen of the male Sole laid open with the organs in their natural position. **G**, gut; **L**, liver.

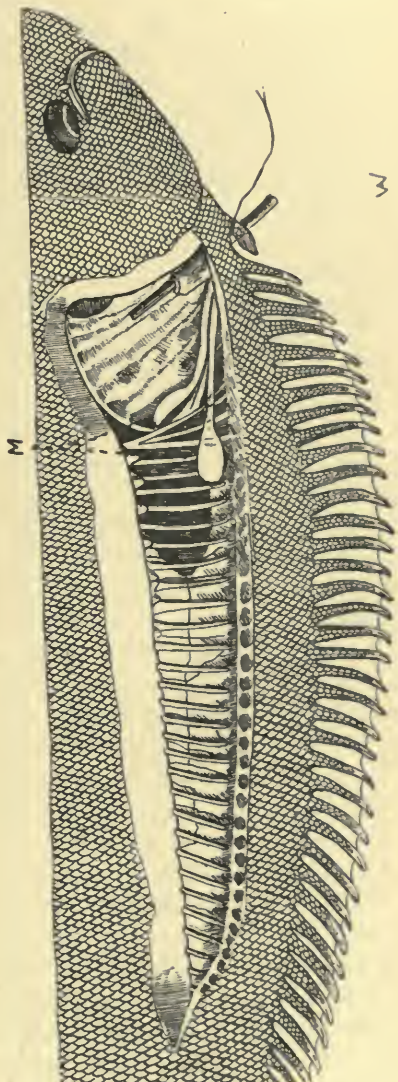


FIG. 37.—The same after removal of the liver and gut. **M**, the milts.

out, but Dr. Fulton has published some of the weights ascertained in a certain number of species. The whole subject requires further study and research, and gives rise to problems which are not only important but attractive. The explanations offered here must not be considered as by any means complete or final, but merely as conclusions suggested by our present imperfect knowledge.

In the herring it has been found that there is very little difference between the weights of the ripe milts and ripe roes, and that little is on the side of the milts. In the cod the ovaries were found to weigh between two and three times as much as the milts. In the plaice the roes were about seventeen to twenty times as heavy as the milts, in the flounder about forty times, while in the sole the inferiority of the milt in size reaches its extreme. The obvious difference between the herring and the other fishes mentioned is that the spawn of the former is attached to solid objects while the eggs of the latter become free and separate in the water. Milt when shed into the sea-water diffuses through a large quantity of it quickly and so becomes much diluted, and as the water of the sea is usually moving in the tidal currents in one direction or another the milt is also carried away at a certain rate from the place where it is shed. From these causes a considerable proportion of the milt shed by male herrings where the females are spawning has no chance of coming into contact with the eggs at all, but is wasted. It may be said that, while the eggs of some fishes are fixed and those of others buoyant, the milt is always buoyant. We have here an obvious reason why the herring should require a large quantity of milt, and we may conclude that where the milts are as large as the roes a great waste of the male generative material occurs in the process of spawning. On the other hand in cases where the eggs are buoyant and free they disperse in the water and are carried by currents at the same rate as the milt, and the result is the same as though both were confined in a small quantity of still water. There is consequently very little waste of milt, and a smaller quantity suffices to ensure fertilisation. In the cat-fish, which like the herring produces fixed eggs, according to Dr. Fulton's figures as given above the males are in number in excess of the females in the proportion of 100 to 79, but concerning the size of the ripe milts we have no observations. The males of the lump-sucker, of which the spawn is also fixed, are said to be much more numerous than the females, although considerably smaller. But here we have to consider not merely the fertilisation of the eggs but the fact that the male keeps guard over the eggs until they are hatched, and until it is explained how twenty-five females can supply enough spawn to keep one hundred males occupied in paternal nursing duties we can scarcely feel confident that the figures are correct.

It is obvious that the above considerations have no application to the case of differences in the proportion of milt to roe among fishes which agree in producing spawn of the buoyant kind. Other things being equal, we may reasonably suppose that the disproportion will be greater when the eggs are larger. For the quantity of milt required will depend on the number of the eggs, not on their size, and therefore if the eggs are larger the roe will be larger while the size of the milt remains the same, or if the size of the roe remains the same the number of eggs will be smaller, and the milts will be diminished in size. But according to this reasoning the milt ought to be larger in the sole than in the plaice, instead of much smaller as is actually the case, for the eggs in the sole are smaller and more numerous than in the plaice. The most important consideration is certainly the rate of spawning, that is to say, the number of ripe eggs shed at the same time, or in one act of expulsion. Here again more exact determinations are required, but it is a matter of general observation that the cod and allied fishes shed their spawn much more rapidly than the flat-fishes, and among the latter the plaice flounder, and turbot more rapidly than the sole.

The differences in the rate of spawning become very obvious when one is pressing ripe eggs from the various fishes for the purpose of artificial fertilisation. In most cases, for instance in those of the haddock and plaice, a large proportion of the contents of the ripe roes can be squeezed out and fertilised at one operation. On the other hand, when I was studying the eggs of the sole I found always the greatest difficulty in obtaining a considerable number of eggs from a number of spawning fish, while when squeezing the males I never saw large drops of milt escape on pressure as in other species, and had to effect fertilisation by cutting out the milts and mincing and pressing them in a vessel of sea-water. The differences in the rate of spawning are also evident from the condition of different roes when they are minutely examined in the ripe condition. In such roes as those of the cod and plaice a large proportion of the eggs are found to present the same stage of development, so that it is evident that after spawning has once commenced there will be no long-continued production of ripe eggs in succession, but that a large number will be shed in a short space of time, while in the sole, and also in the gurnard, eggs are found in all degrees of development from the most primitive stage onwards. That the eggs of the sole are shed in very small numbers at a time has been strikingly confirmed by the observation of the soles in the act of spawning at the Plymouth Laboratory.[1] Only a small number of fertilised eggs were obtained each day from a tank containing a large number of ripe fish, and the eggs appeared to the observer to be shed one at a time at intervals.

It is evident that if only a few ripe eggs are shed into the water at one time the quantity of ripe milt which must be liberated to fertilise them will be very small, while if several hundreds or thousands of eggs are expelled within a few seconds or minutes within the same time a hundred or thousand times as much milt will be required as in the other case. If the formation of the milt occupied as long a time as that of the eggs, there would be no apparent reason why the proportion in size between the male and female organs should differ greatly in fishes that spawn rapidly and those that spawn slowly. In both roe and milt there would be a bulky accumulation of eggs and sperms in process of development. But in the egg there is a gradual formation of yolk which extends over weeks or months, while the sperms are minute, contain a small quantity of material, and can be produced in a few hours. In this fact lies the reason why a slow spawning roe is so much larger than the milt of the same species. If we suppose that 5,000 ripe eggs are shed by a sole per day in the spawning period, and that the growth of an egg takes three months, then a sole producing 500,000 eggs would take 100 days to get rid of all its eggs, and on the day it commenced to spawn very nearly all the eggs would be present in the roe in all stages of development or formation. On the other hand it is extremely probable that the ripe milt necessary to fertilise 5,000 eggs can be produced in one day or a few days, and therefore at the commencement of spawning the male organ would contain not all the milt to be shed in the spawning

[1] G. W. Butler, B.A.: "On the Spawning of the Common Sole in the Aquarium," *M. B. A. Journal*, vol. iv., No. 1, p. 3.

period but only the small quantity required for the first day or first few days, more being produced after the first quantity was shed.

The comparison of the grey gurnard with the angler with respect to the relations of the sexes and the rate of spawning corresponds to that between the sole and plaice. The gurnard spawns gradually, and although no special observations have been made on the size of the milts there is, according to Dr. Fulton, a very great inferiority on the part of the males in point of number, the females being more than four times as numerous. In the angler, on the contrary, all the eggs are shed simultaneously, and the males were found to be more abundant than the females in the proportion of 100 to 26. There is, however, an additional reason why in the angler a large quantity of milt should be necessary. The eggs although buoyant do not separate, but remain connected together in a continuous sheet. Owing, therefore, to the diffusion or scattering of the milt in the water there is doubtless a considerable waste of that substance in the process of fertilisation.

Although the small size of the milts in the slow-spawning fishes, especially in the sole, has attracted most attention, it is also true, as might be expected, that the roes in these species are smaller in the spawning season than in fish which spawn quickly. Ripe eggs being larger than partially developed eggs, the more ripe eggs present at the same time the more enlarged will be the roe. But for the reasons already given the differences are not so extreme as in the case of the male organs. Dr. Fulton has referred to the very different degree of ease with which the eggs are carried in different species. In the plaice, flounder, cod, haddock, and several others, all producing large numbers of ripe eggs simultaneously, the body is much swollen or distended by the ripe roes in the spawning season, while in the sole, gurnard, and others the enlargement of the belly in the gravid condition is much less striking. Great enlargement or distension of the body of course implies that the ripe roes are larger in proportion to the size of the fish than in the opposite case. The internal organs, especially the stomach and intestines, are necessarily compressed by the enlarged roes, and this is the reason why so many fishes take little or no food during the spawning period. Gravid female cod, for example, are taken in large numbers by trawlers in the spring of the year when the line fishermen catch none but male, immature, or spent fish.

To return now to the consideration of the size of the male fish in comparison with that of the female, it cannot be said that the differences are at present fully explained. The size of the male which produces the milt is of no importance to fertilisation. It appears however that the male fish are smaller than the females in those species in which the milts are much smaller than the roes, although there is by no means a close correspondence between the fish and the milts in this respect. For example, the males in the cod and similar fishes are usually larger than the females, although the milts are smaller than the roes, and in the sole and other flat-fishes the males are by no means as inferior in size as are the milts in comparison with the roes.

Owing to the fact that fertilisation of the eggs of bony fishes naturally takes place in the water outside the bodies of the parent fish, and in consequence of the ease with which the ripe milt and eggs can be obtained from the fish by gentle pressure on the abdomen, artificial fertilisation of the eggs is rendered possible and in most cases easy. All that is required is to squeeze the ripe eggs and a little ripe milt into a vessel of clean sea-water. But in the practical application of this process the questions of the rate of spawning and the size of the soft roe are of considerable importance. In the case of fishes which spawn rapidly—for instance, the herring, cod, plaice, or flounder—all or a large proportion of the total number of eggs produced by the fish in one season can be fertilised at one time. The hatching of the eggs so obtained depends on placing them under conditions suitable to their healthy life. But in certain cases artificial fertilisation is difficult. For instance in the sole only a small number of ripe eggs can be obtained from a single fish, and to fertilise these it has generally been found necessary to open the male fish, take out the small milts, and squeeze them up in the water containing the eggs. It has been found preferable to keep the spawning fish in ponds suitably arranged, and collect the fertilised eggs naturally shed. In this way the risk or certainty of injuring the fish by squeezing is avoided. But here in some cases another difficulty arises. The plaice and cod under such conditions are found to spawn freely, but until the year 1895 the sole had never spawned in the tanks of the Plymouth Aquarium, although numbers had lived in health there for years. It was found that the female fish became swollen in the spawning season as though the roes were enlarged, but no soles' eggs appeared in the tank, although in the same tank plaice spawned freely. After a time the swelling of the females began to diminish, and on killing some and opening them it was found that the cavities of the roes contained the dead and shrunken remains of ripe eggs. Evidently in consequence of the conditions of confinement the eggs after developing were not shed in the natural way, but died within the roe, and were then gradually expelled. Turbot and brill have also hitherto failed to spawn in confinement. In squeezing fish to obtain fertilised eggs it is important that only ripe eggs should be pressed out. If too much pressure is applied some of the unripe also escape, and can easily be distinguished by their smaller size and chalk-white or yellowish appearance.

The spawning season of a fish is the period during which some individuals are found to be ripe, and it may last three, four, or five months. The majority of our common sea-fishes spawn in the first half of the year. The plaice is one of the earliest, beginning to spawn in January and going on to the middle or end of April. The cod spawns in the North Sea from February to May, the sole from April to July. The herring appears to have two spawning periods—one in winter or spring, one in summer or autumn, in the same neighbourhood, the dates differing in different districts. But there is good evidence that like other fishes the same herrings spawn only once a year, and that there are races which spawn in winter and others which spawn in summer, the spawning grounds of the former being nearer shore and nearer the mouths of rivers than those of the latter.

There is one family of fishes which forms an exception to the general rule in the circumstances of its generation. This is the family of the eels. Much still remains obscure and unknown in the life-history of the eel and conger, but what is known is sufficiently remarkable. Ripe eels have never yet been obtained, all that is known of them is that they go down the rivers in autumn to the sea, and probably spawn there, and that young eels two to four inches long return in the following spring up the rivers. It is fairly certain that the old eels die after spawning.

Ripe conger have never been taken from the sea, but they live well in aquaria, and from study of them in that condition it has been found that the males are very much smaller than the females, that the females after feeding and growing for several years cease to feed, and that their roes then develop. The eggs of the conger are very small, and the roes are not closed sacs but open ribbons with the eggs on one side. The males in aquaria become ripe: the fish do not exceed two and a half feet in length, but the milts are large, filling the whole belly cavity: they live about six months in the ripe condition without feeding and then die. The females also die with enormously enlarged roes, but before the eggs have become ripe. There can be no doubt that in the sea conger of both sexes die after spawning. The eggs of some fish of the eel family have been taken in the sea, but those of the conger are not yet known. It is known that the fecundity is great, various calculations having given the number of eggs in a single female at from three to seven millions. The females appear to be not only larger but more numerous than the males.

CHAPTER IV

THE EGGS AND LARVÆ AND THEIR DEVELOPMENT

IT follows from the description of their formation, given in the preceding chapter, that the large egg of a dog-fish or skate consists, like a hen's egg, of three parts, the shell, the white, and the yolk. The shell differs from that of the bird's egg in shape colour, and substance. In shape it is somewhat oblong with a tendril or a straight horn at each corner. Fig. 38 shows the shape

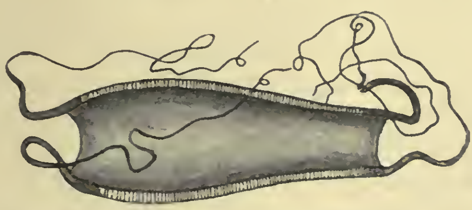


FIG. 38.—Egg of the Larger Spotted Dog-fish, or Nurse-hound ; after Day.

of the egg of the larger spotted dog-fish ; the eggs of the skates and rays have horns instead of tendrils, and are broader in proportion to their length. The colour is from light brown to black, deepening gradually after the eggs are laid. The substance of the shell is tough, fibrous, and flexible, and contains no lime, the presence of which in large proportion causes the shell of the bird's egg to be hard and brittle. The white, as in the bird's egg, is a thick transparent liquid. The yolk contains the essential part of the egg, namely a spot of living substance on its surface which is the germ. No distinct membrane appears to exist on the surface of the yolk. The yolk itself is yellow in colour, of a semi-liquid character, but made up of minute drops..

The development of the young fish in these large eggs, whether inside or outside the mother, takes several months. Except in a few species, none of which are common in British waters, there is no difference in the course of the development between the eggs which develop in the egg-tube or uterus and those which develop in sea-water. The process commences by the growth of the germ into a membrane or skin which spreads round the yolk. At one point this skin is, as it were, pinched up and thickened to form the commencement of the young fish, which is called the embryo, and at first is very small compared to the ball of yolk on which it lies. The embryo as it grows and develops is nourished by the yolk, which therefore gradually decreases. When the gill-slits are formed, long thread-like gills develop and hang out a long way beyond the slits as delicate fringes. When the embryo has acquired generally the shape of the young fish it is connected with the yolk by a narrow hollow stalk, and the interior of the yolk-sac communicates with the interior of the stomach. This stalk is situated just behind the front pair of fins, and when the young fish is hatched or born the yolk and the stalk have disappeared, the last sign of them being a sort of navel or soft place in the belly where the yolk-stalk was previously situated. No part of the yolk is separated, it simply dwindles away as it is gradually consumed to nourish the developing fish. The gradual growth of the little fish in the egg of the smaller spotted dog-fish can be seen through the partially transparent shell, and has been on view from time to time in the aquarium of the Association at Plymouth.

The young fish when hatched or born has all the characters of the adult fish, and immediately enters upon the same mode of life.

The eggs of the bony fishes consist only of the yolk containing the germ, and surrounded by the enclosing membrane. It is better to avoid calling the latter the shell, because it is different in nature from the shell of the bird's egg or of that of the dog-fish. The eggs of different kinds of these fishes differ in size, in proportional weight, some being heavier and some lighter than sea-water, in the character of the membrane, in the proportion which the quantity of the germinal matter bears to that of the yolk, and lastly in the appearance and structure of the yolk itself. These differences do not correspond in all cases to the differences between the adult fishes, although sometimes certain peculiarities of the egg are found in all the members of one family and not in other families.

The character of the enclosing membrane is important, because it has a good deal to do with the conditions under which the eggs are placed during development. With respect to these conditions the eggs are of three kinds: (1) those which are heavy, but free or separate; (2) those which are heavy and attached; (3) those which are light and separate. The last kind occur only in the sea.

Of the first kind the salmon family supply the most important instances. In eggs of this kind the outer surface of the egg-membrane is smooth, without projections, and hard, so that the eggs have no tendency to adhere to one another or to surrounding objects. The eggs of salmon and trout are deposited in the gravel of the bottom of running streams, the female fish digging a trough in the gravel, in which she deposits the eggs, and then heaping more gravel over them. The eggs of the salmon are about one-fourth of an inch in diameter. The eggs of the shads also lie at or near the bottom in a free condition, and are deposited in the tidal water of estuaries, or in the fresh water of rivers. The only other case among British fishes is that of the turbot (*Lota vulgaris*), which, though a fresh-water fish, belongs to the cod family. Its eggs lie loose and separate at the bottom of the water.

Heavy adhesive eggs are laid by nearly all other fresh-water fishes, and by a great many marine fishes which live near the shore. In the majority of these the surface of the egg-membrane is smooth but sticky when the egg is first laid, afterwards hardening and so firmly attaching the eggs to one another or to other objects in the water. The eggs of the sturgeon are attached to stones, &c., at the bottom of rivers. The eggs of the carp family, all of which live in fresh water, are attached to water plants, and so also are those of the pike and other members of the pike family. The eggs of the herring are similar in this respect. Each egg of this fish is six-hundredths of an inch in diameter. The spawn is deposited on rough gravelly or stony ground, or shingly banks in the sea at various distances from the shore, or in certain cases, as in the Baltic, in estuaries where the water is so fresh that the spawn is actually found attached to fresh-water plants. Fig. 39 shows the appearance under the microscope of a single herring egg in the living condition with parts of the membranes of its neighbours to which it adheres. It is worth noting that round adhesive eggs can only touch one another and stick to one another at separate places, not all over the surface. There are thus in a clump of eggs spaces or channels left where the eggs are not touching, and where, therefore, water can pass through the mass. However, in spite of this, a clump or mass of adhesive eggs sticking together is more difficult to

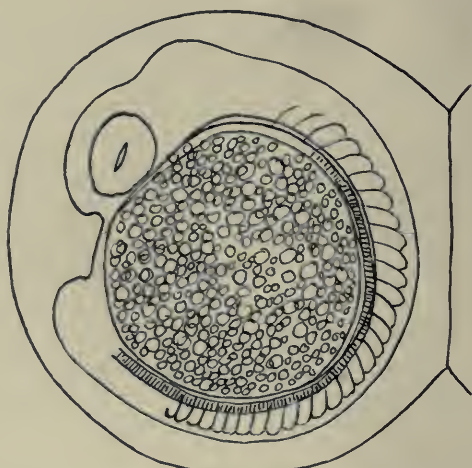


FIG. 39.—Living Egg of the Herring, magnified.

keep alive than an equal number of separate eggs, in consequence of the liability of the eggs in the clump to become suffocated. Living eggs, like living fishes, require a constant renewal of clean water, water containing dissolved air, and the more eggs there are in a small space the more rapid the change of water which is necessary to them. In natural conditions, herring spawn receives a sufficient change of water from the flow of the tides. The herring is the only one of the British members of its family whose eggs are of the adhesive or fixed kind. We have seen that the eggs of the shads are free and develop at the bottom of the water, while the eggs of the sprat and pilchard are free and float in the sea. In the perch family, among the spiny-finned fishes, the fresh-water perch attaches its adhesive eggs to fresh-water plants, while the bass (*Labrax lupus*) and other marine forms produce floating eggs. The commoner fishes whose adhesive spawn is deposited near the sea shore are the gobies, the blennies, the suckers, and the shallow-water Cottidæ, commonly called sea-scorpions or hard-heads. The eggs of the common blenny or shanny are attached in a single layer to the surface of rocks. Those of another species which were examined at the Plymouth Laboratory were attached to the sides of the empty marrow-cavity of an old beef-bone. The eggs of the

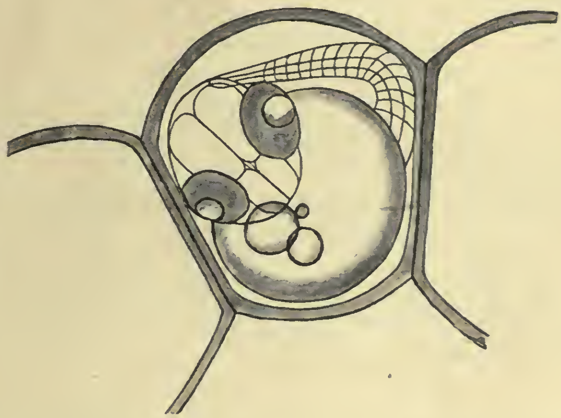


FIG. 40.—Egg of the Sea-snail (*Liparis*) as seen when alive and magnified.

gunnel, another member of the blenny family, form a round mass which is not fixed, but lies free on the ground. The cat-fish or wolf-fish is the largest fish of the same family, being usually two or three feet in length and sometimes reaching six feet. Its eggs were discovered by Prof. McIntosh to be large and fastened together into a mass of considerable size lying on the sea-bottom. The eggs of the two species of *Cottus*, the sea-scorpion and the father-lasher, so well known for their large round heads, armed with strong spines behind, form small roundish masses attached to stones, rocks, &c., between tide marks.

The eggs of the lump-sucker are large, and deposited in irregular masses of considerable size not far from low-water mark ; those of the sea-snails or diminutive suckers (*Liparis*) form rounded masses not much larger than a marble, which are attached to the forks of branching zoophytes, very frequently to a species which is common on the east coast and called *Hydrallmannia*. This spawn has been frequently mistaken both by fishermen and naturalists for the spawn of the herring, especially in former years before the characters of the eggs of different fishes had been thoroughly investigated. The individual egg, however, is a little smaller than that of the herring, and, as seen in Fig. 40, has an altogether different character. The yolk contains several oil-globules. The still smaller sucker fishes,

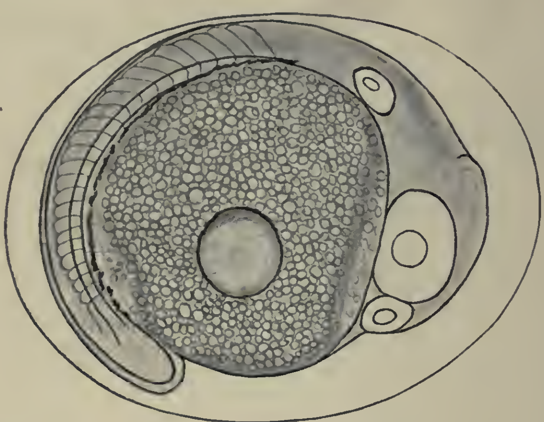


FIG. 41.—Egg of the Double-spotted Sucker (*Lepadogaster*).

called *Lepadogaster*, deposit their eggs, which are oval and somewhat flattened, on the inner surface of empty shells. Fig. 41 shows the egg of one of these, the double-spotted sucker. The eggs of the gobies are peculiar, having a long, spindle-like form, one end of which is attached to a smooth surface by means of fibres which project all round it and form a network, somewhat like rootlets (Fig. 42).

Eggs which are free and carried about at the mercy of tides and currents cannot receive any care or protection from the parent fish, but marked parental solicitude and exertion are exhibited by many of the commercially useless fishes which produce attached eggs. As a rule it is the male parent which in these cases undertakes the duties of a nurse. The male gobies make a home for the eggs, it can scarcely be called a nest, and remain in it until the eggs are hatched. The common sand goby when about to become a father scoops out the sand from beneath an empty shell, usually that of a *Pecten* (commonly called clam, or scallop), and invites females to lay their eggs in the domicile thus simply prepared. The female deposits her eggs on the lower surface of the shell, which forms the ceiling of the nursery, and the male remains on guard. The action of his pectoral fins is necessary for the well-being of the eggs, for without their movement the eggs would die of suffocation. The object of the father's exertions is therefore chiefly to secure aquatic ventilation of the cavity in which his progeny are developing. The butter-fishes or gunnels, common shore fishes belonging to the blenny family, roll the eggs into a ball after they are laid by coiling their bodies round the mass, the male and female taking possession of the eggs alternately. Fig. 43 is from a sketch of one of these fishes with a mass of eggs as observed in the St. Andrews Laboratory by Mr. Holt. The parents remain with the eggs until they are hatched.

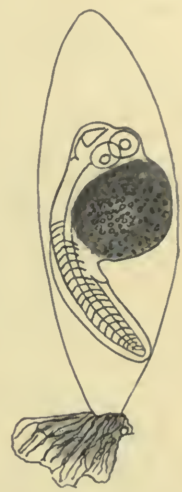


FIG. 42.—Egg of a species of Goby, from lower side of stone on shore at Falmouth.

The large lump-sucker (*Cyclopterus lumpus*) is another species in which the male keeps guard over the eggs and keeps up an artificial flow of water over and through the mass of spawn, which is attached to rocks, posts, or piles in the water. There are also fishes which are true nest-builders. The commonest instances of this are afforded by the sticklebacks (*Gasterosteus* and *Spinachia*). Two species live in fresh water, the three-spined and the ten-spined, but the larger fifteen-spined species occurs in the sea near shore, and in the brackish waters of estuaries. According to Buckland's descriptions the nest of the fresh-water forms is made of fibrous materials resting on the ground, with a hole in the top, and the male fish frequently places himself above the nest with his snout towards the opening, fanning the eggs inside with his pectoral fins. But the sea stickleback makes a nest by binding loosely together the fronds of growing sea-weeds by means of a thread which he spins from his own body. It has recently been proved that this thread is a secretion from the kidneys, which is produced only in the breeding season.

The mode in which the eggs are protected in the pipe-fishes is still more remarkable. They might fitly be called the kangaroo-fishes, but the pouch is in the male parent instead of the female. The male in the common or larger brown pipe-fish, and in the broad-nosed pipe-fish, which is green in colour, has a pouch beneath the tail behind the vent. The pouch is formed by two long thick folds of skin which meet in the middle line, but are not joined together. Into this pouch the eggs are

FIG. 43.—Butter Fish with its mass of spawn; after Holt.

received when shed by the female, the male fertilising them at the same time, and there they remain until they are hatched, when the young pipe-fishes, which are about an inch and a half long and similar to their parents, escape. In the snake pipe-fish, the body of which is smooth and rounded, there is no pouch, but the eggs are attached to the skin of the male in front of the vent. One species called the worm pipe-fish is very small and slender, and is often found under stones at low tide, on the south coast.

It has been mentioned that the eggs of the gobies are attached not simply by an adhesive surface but by special threads or fibres. Such special modes of attachment of varying kinds occur in the eggs of other fishes. In some adhesive eggs of the ordinary kind there are indications that the egg-membrane is composed of two layers, an inner and an outer. In the egg of the smelt or sperling (*Osmerus eperlanus*), one of the salmon family, the outer layer breaks at one part of the surface of the egg and separates, turning inside out as it does so, and remaining firmly attached only at one small circular patch. The separated membrane is adhesive when the egg is first shed, and attaches itself to objects in the water, *e.g.* the piers of bridges or posts in the rivers where the fish spawns, or the stones of the river bed. The eggs are thus suspended from their support by the flexible outer membrane (Fig. 44). It has been mentioned that in all the eggs of bony fishes there is a small opening in the egg-membrane called the micropyle, through which the sperm enters in the process of fertilisation. In the egg of the smelt this opening is in the centre of the circular patch over which the suspending membrane remains attached.

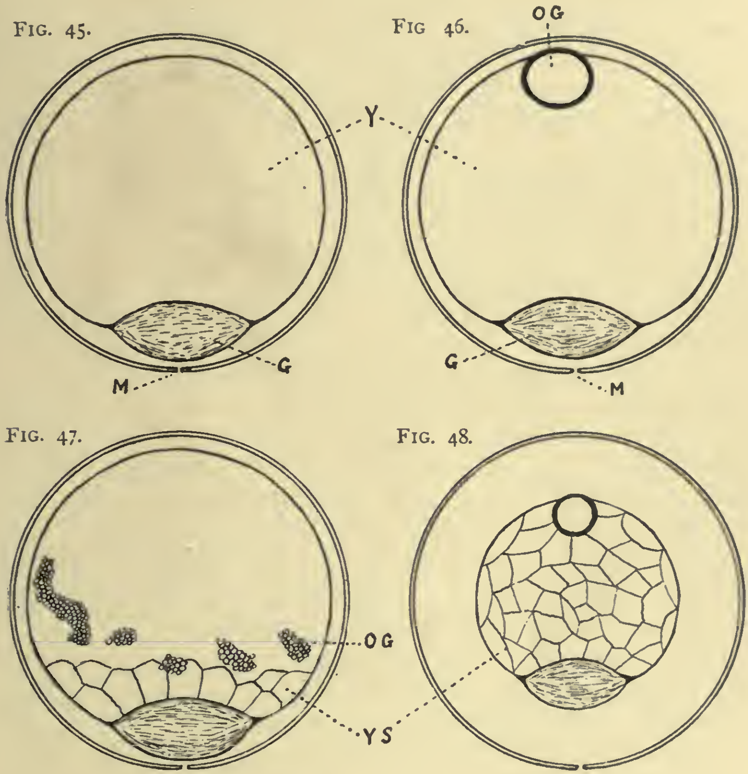
FIG. 44.—Egg of the Smelt, with its suspending membrane.

In other cases the outer membrane is represented by threads or cords which are attached to the egg-membrane at two opposite regions and become fastened to foreign objects or entangled with those of other eggs of the same fish by their free outer ends. This is the case in the eggs of the gar-fish or long-nose (*Belone vulgaris*) and other fishes of the same family, namely the skipper or saury pike (*Scombresox*) and the flying-fishes (*Exocœtus*). The conditions under which the eggs of the gar-fish are naturally placed in British waters have not been thoroughly ascertained, but Day mentions that Mr. Dunn sent him in May 1881 a portion of a mackerel net to which a number of the eggs of this fish were attached by means of their filaments. These eggs had been shed by the fish when captured, as frequently happens, in the mackerel net. Masses of eggs held together by the tangling of such filaments have been more than once described; they have been obtained in the open Atlantic in tropical latitudes, and probably belong to flying-fishes.

After fertilisation the egg-membrane in the eggs of all bony fishes separates from the yolk mass within it, and at the same time the germinal matter collects together and forms a mass lying upon the yolk. The proportion which the mass of germinal matter bears to that of the yolk varies considerably, in the herring the former is nearly as large as the latter, but usually it is very much smaller. In the eggs hitherto mentioned the yolk consists of a number of globules of various sizes, held together by a network of strands connected with the germinal mass. In most cases there are also a few globules of a different kind, consisting, in fact, of oily matter, at the surface of the yolk mass. In consequence partly of the granular nature of the yolk and partly of its separation into these numerous globules, adhesive and heavy eggs are not very transparent, although generally sufficiently so to allow of the embryo and internal parts of the egg being seen to some extent in the living condition of the egg. Herring eggs are rather more transparent than the majority of adhesive eggs.

The third kind of eggs, those which float about in the sea, are remarkable for their great transparency. It is difficult to distinguish them when present in small number in a bottle of clean sea-water. This is due partly to the transparent character of the yolk itself, partly to the fact that it is not disposed in a number of separate globules, but usually forms a single undivided mass surrounded by germinal matter in a thin layer on the outside. The character of a typical floating egg, such as that of the cod or plaice, is shown in Fig. 45. All the parts of the egg are clearly seen when it is examined in the living condition with the microscope. After death and when preserved in the liquids used by naturalists for the purpose the eggs become opaque. The egg is made up of the membrane surrounding it, and the mass of the egg proper, consisting of the germ, *G*, and the yolk, *Y*. In such an egg there are no oil-globules and no divisions in the yolk. The following are the fishes which are known to have such eggs, the spawn of each of them having been examined by naturalists—cod, haddock, whiting, bib, poor-cod, pollack, coal-fish, plaice, flounder, dab, lemon sole or merry sole (*Pl. micro-*

cephalus), witch or pole dab ; all of which belong either to the cod family or the flat-fish family. Of these eggs that of the plaice is the largest, being about $\frac{1}{12}$ inch in diameter, and that



FIGS. 45–48.—Diagrams of the chier types of floating marine fish-eggs. 45. Egg of Plaice, Cod, &c., with undivided yolk. 46. Egg with simple yolk and single oil-globule. 47. Egg of Sole with yolk beneath the germ divided into segments and groups of minute oil-globules. 48. Egg of Pilchard, with yolk wholly divided, and also a single oil-globule. **G**, germ ; **O G**, oil-globule ; **Y**, yolk ; **Y S**, yolk segments ; **M**, micropyle.

of the dab is the smallest, being less than $\frac{1}{25}$ inch ; the rest are of sizes intermediate between these.

A large number of sea-fishes have eggs which differ from these only in the presence of a single large oil-globule, situated not in the interior but at the surface of the yolk (Fig. 46). When the egg is first shed the oil-globule is movable, and when the egg is placed on a glass slip under the microscope, and rolled over, the globule always floats to the uppermost point. When the embryo develops, however, the globule becomes fixed by the germinal membrane in a position beneath the tail end of the embryo. Sometimes three or four globules are present in the egg when shed, which afterwards run together into one. Eggs of this kind occur in a large number of different families. Many species of the cod family and flat-fish family have them, namely the rocklings (*Motella*), the hake (*Merluccius*), the ling (*Molva*), the turbot and brill (*Rhombus*), the topknots (*Zeugopterus*). Among the spiny-finned fishes eggs of this kind have been discovered to belong to the following: the mackerel, the gurnards, the gray mullets, and the bass. The single oil-globule may be present in conjunction with other conditions of the yolk.

The next complication to be considered affects the yolk, and consists in the division of the part of it beneath the germ into a layer of separate segments, while the rest is undivided. The egg remains transparent, the partitions between the segments, composed of germinal matter, being very delicate. This condition is known to occur in the common sole and other kinds of sole among the flat-fish family. In the common sole (Fig. 47) there are also a number of very minute oil-globules which are arranged in irregularly shaped patches on the surface of the yolk and give the egg to some extent a chalk-white appearance when it is seen floating in a bottle of water. The same condition occurs in the red mullet (fam. *Mullidæ*) with a single large oil-globule in the yolk, and in the dragonet (goby family) with no oil-globule. It occurs also in an egg supposed to belong to the American blue-fish, one of the same family as our scad or horse-mackerel, in the egg of which also it is probably present.

A still further complication in the structure of the yolk consists in the complete division of it into segments, which like the condition last described may occur together with the presence of an oil-globule or without. Floating eggs having this peculiarity are scarcely less transparent than those which have a simple yolk. It is found in the floating eggs of the sprat and pilchard: in that of the sprat there is no oil-globule, in that of the pilchard (Fig. 48) there is one. It occurs also in the egg of the anchovy where there is no oil-globule, but the shape of this egg is not round but sausage-like. The yolk is divided up in this way also in certain floating eggs found at Naples in which there were several oil-globules. These eggs may be considered with confidence to belong to some fishes of the eel family, but which particular kinds cannot be decided. It is not known that our common eel, or the conger, have floating eggs.

It is interesting to notice that this last condition of the yolk in floating eggs is the one which differs least from its condition in attached heavy eggs, in which the yolk is always composed of a number of separate globules. When the yolk has an outer layer of separate segments it is in an intermediate condition, and when it is not divided at all it is most altered from its condition in fixed eggs, all the globules having run together into one large globe.

One other peculiarity among floating eggs remains to be mentioned. In the majority the space between the membrane and the yolk is not large, the two are in contact at more than one point. In a few, however, there is a much greater separation between the two, so that the yolk is only about half as wide across as the envelope which contains it. This is the case in the egg of the pilchard (Fig. 48), in that of the long rough dab among the flat-fishes, and probably also in the halibut.

There is scarcely any time of year or any part of the sea in which floating eggs of some kind of fish cannot be found. As a rule, however, they are not visible from a boat or vessel, it is necessary to collect them from the sea-water by means of a tow-net, a simple apparatus in the shape of a bag with a ring of iron or cane to keep the mouth open, and made of some kind of cloth which will allow the water to strain through. There are many substances which grow in the sea at the surface and near it and which may be mistaken for fish-spawn. One of these is very common, and usually very abundant in May and June, when in calm weather it forms a visible scum on the surface. This consists of little round grains, which under the microscope have the appearance shown in Fig. 49. They belong to the lowest and simplest classes of living things, and do not grow into anything else. These grains have the power like many other marine creatures of giving out light in the dark, and hence are called by naturalists Noctiluca, or "night-light." They are among the principal causes of the phosphorescence of the sea. The scum they form has usually a salmon-pink colour.

There are a few cases in which floating eggs instead of being free and scattered are enclosed in large numbers in a single sheet or mass of transparent jelly-like substance. The spawn of the frog-fish or angler (*Lophius piscatorius*), for instance, was found by Prof. Alex. Agassiz in America to form an immense gelatinous band from two to three feet broad and twenty-five to thirty feet long. Each egg has a simple yolk and a single oil-globule, and the band is formed of the eggs of a single female sticking to one another by the surfaces of their enclosing membranes, the whole floating free in the sea. The band or ribbon does not always float at the surface. A portion of one was brought up in a trawl in Mount's Bay. In British waters it has been obtained more than once. A quantity was once brought alive to the Plymouth Laboratory, and it has been taken on the coast of Scotland.

FIG. 49.—A single globule of Noctiluca.

When the eggs of the bony fish are laid they have not been fertilised, and the young fish have not begun to develop in them. It has been explained that they come into contact with the male generative substance in the water, and that one of the sperms enters each egg through the micropyle and penetrates into the germ. Before the egg is shed, when it is taken in a perfectly ripe condition from the roe of the female, the membrane is in contact with the contained substance, and the germinal matter forms a thin layer all round the yolk. Whether the egg is fertilised or not, certain changes take place in it when it passes into the sea-water. The membrane separates from the egg, and the germinal matter collects into a mass on one side of the yolk. If the egg is not fertilised no further changes occur in it; after a time it dies and then putrefies. But if it is fertilised then a further process of change goes on which converts the egg into a young fish. This process is called the development of the fish. We may consider the life of the individual fish to commence the moment the egg from which it arises is fertilised. This life consists of four distinct stages or periods, of which the stage of development in the egg is the first. The second stage commences after the fish is hatched. At this time it is not like its parents, but very different, and is usually called a larva. When a butterfly is first hatched it is a caterpillar, a very different creature, and it has to go through a transformation before it becomes a butterfly. The fish likewise goes through a transformation, and the stage from hatching to the completion of this transformation is the second period of its life. The fish, however, after its transformation is still very small and is not mature, its generative organs are not fully developed, and therefore it does not begin to breed. The period from its transformation to its maturity is the third period of its life, and the fourth is that of the mature adult condition which is terminated sooner or later by death.

The development of the egg of the bony fish differs from that of the dog-fish or skate in many important matters, but there is a general similarity between the two cases. In the bony fish the duration of the process is much shorter, and the fish when hatched is in a much less perfect condition. In fact in the case of the dog-fish the first and second periods of life just defined are not separate at all, but both included in the period of development inside the egg-shell. This will be more fully explained when the larva and its transformation are described.

The first step in the development of the bony fish is the division of the mass of germinal matter into portions which remain connected. It is by the continual division and growth of these portions that the development of the fish is brought about. The germinal matter is thus converted from a single mass of substance into a compound "tissue" from which the flesh and organs of the embryo are formed. At first the tissue becomes thin and forms what may be called the germ-skin, which spreads out over the surface of the yolk until it completely encloses it. But from about the centre of this germinal membrane to its edge there is a thickened rod, which marks the back of the young fish (Figs. 51, 52). The inner end of this rod, that which is in the centre of the germinal membrane, is thicker than the rest, and this part is the commencement of the fish's head. At the sides of this part appear two circles marking out the future

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FIG 50.

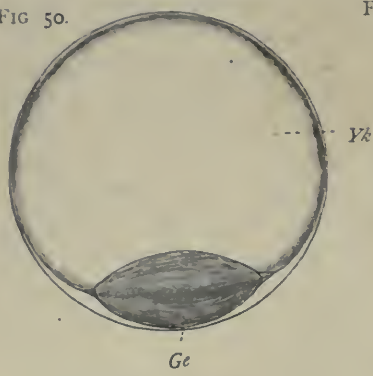


FIG 51.

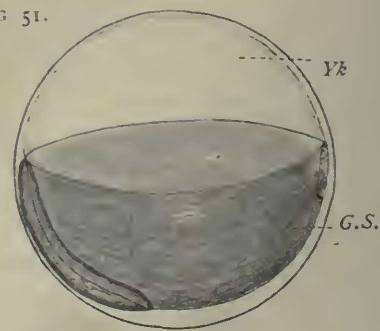


FIG 52.

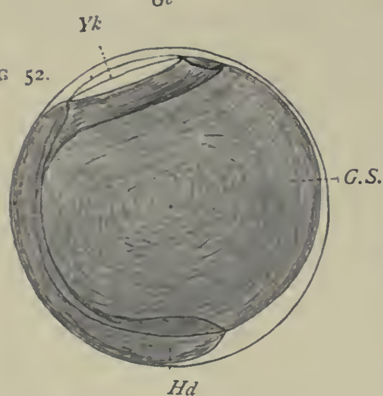


FIG. 53.

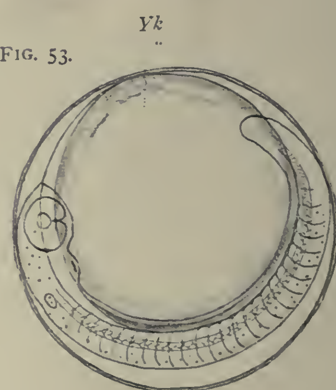
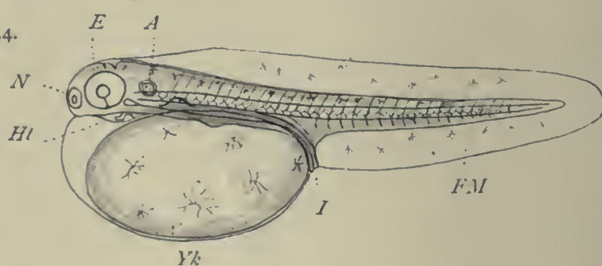


FIG. 54.



FIGS. 50-54.—The development of a buoyant marine fish-egg. 50. The fertilised egg. 51. The same when the germ-skin has spread over half the yolk. 52. The same when the germ-skin has nearly enveloped the yolk. 53. The same when the embryo is advanced in development, and the tail has begun to grow out. 54. The newly hatched larva. **Yk**, yolk; **Ge**, germ; **G.S**, germ-skin; **N**, nostril; **Hd**, head; **Ht**, heart; **A**, organ of hearing; **E**, eye; **I**, end of intestine; **F M**, fin-membrane.

eyes, and behind these a cavity on each side becomes the ear. After the yolk has been completely enclosed by the germinal membrane the little "embryo" still goes on growing at its hinder end, and the result of this is the formation of the tail (Fig. 53).

When the buoyant egg is left to itself in still water it always floats with the germ or germ-skin downwards, because this is heavier than the yolk. It should be noted that eggs do not float because they have an oil-globule, since in a very large number of floating eggs there is no separate oil-globule: they float because they are lighter than sea-water, and they do not float in fresh water, nor when they are unripe, nor when they are dead.

The intestine, including under that term the greater part of the food-pipe, namely gullet, stomach, and intestine, is formed as a simple uncoiled tube. When development has reached this stage it is easy to see that the yolk is now a large mass within the belly of the little fish, which is greatly swollen by it. The thickened rod is formed by, or becomes in the process of growth, the flesh or muscles of the back of the little fish, and in the centre of these is a slender rod around which the bones of the spine are afterwards formed. There is no mouth. The fins arise as simple flaps of skin without bones; one of these in the middle line runs along the back round the end of the tail, and forwards again beneath the latter to the yolk. The breast fins appear as a delicate flap on each side behind the head: the hinder fins do not appear till later.

In the condition now described, in the case of buoyant separate eggs, the little fish is hatched, that is to say the egg-membrane bursts because it is no longer strong enough to resist the growth and movement of the tail, and the little larva is set free (Fig. 54). It is not difficult now to understand why the fish when first hatched is called a larva, to mark its difference from the fully developed fish. It has no mouth to feed with, no red blood, and no bones. At first it floats upside down, because there is still so much yolk, and the yolk is lighter than the body. It goes on developing, nourishment as before being provided by the yolk. On the newly hatched fish there are little stars of colour, the tint and arrangement of which are different in different species. These are the pigment-cells which are formed in the skin and other parts, and which begin to appear some time before hatching.

The time occupied in the development of the embryo in the egg differs in different species, and in the same species differs according to the temperature of the water in which the eggs are contained, being quicker when the water is warmer, slower when it is colder. It varies from three or four days to as many weeks in the case of buoyant eggs, but is longer in the case of some of the larger attached eggs.

The larvæ hatched from buoyant eggs are very small: one of the largest, that of the plaice, is only $\frac{1}{3}$ inch in length. The larvæ hatched from attached, adhesive eggs are usually more developed, and differ among themselves in size and degree of development. Such eggs are in nearly all cases larger than buoyant eggs, they have a larger yolk and a stronger egg-membrane: the larva therefore remains within the latter for a longer time, and does not leave it until it has reached a more advanced condition. Usually the mouth is open and the jaws are somewhat developed, and there is red blood in the veins. Among the most advanced fish at the time of hatching are the salmon and trout, in which the longitudinal fin-membrane is already separated into portions indicating the permanent fins. Fig. 55

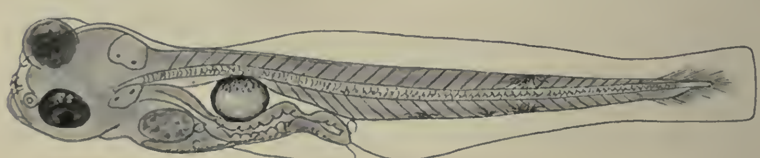


FIG. 55.—Newly hatched young (larva) of the Common Black Goby.

shows the condition of the young of the black goby when first hatched.

For some days the fish larva hatched from buoyant eggs, such as the larva of the plaice or cod, continues to develop without taking food, being nourished by the mass of yolk it still possesses. The quantity of yolk continually diminishes; the mouth appears first as an opening on the lower side of the head, as it is in the full-grown dog-fish, and then is carried to the end of the snout by the growth of the jaws. The pigment in the body increases, the eyes becoming quite black, though the rest of the body remains very transparent. Black pigment in the eye is necessary for vision. By the time the yolk is all gone, which is about four or five days after hatching, the fin-membranes are somewhat broader, but there are no fin-rays in them, nor any bones in the body. The breast-fin is a rounded flap behind the head, the second pair of side-fins are either small or not yet developed.

FIG. 56.

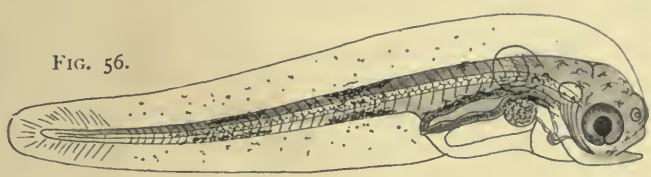


FIG. 57.

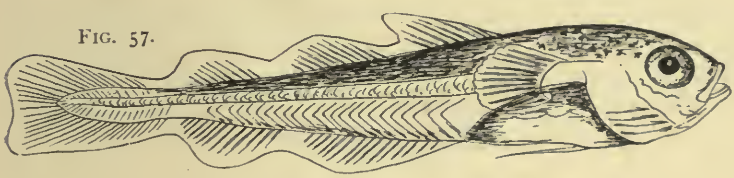
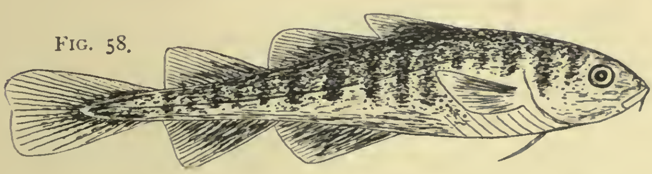


FIG. 58.



FIGS. 56–58.—Three stages in the development of the Cod, showing the transformation of the larva into the perfect form. The larva represented in Fig. 56 is a little over $\frac{1}{5}$ inch in length. At the stage of Fig. 57 the young fish is just 1 inch long, at that shown in Fig. 58 it is about $1\frac{1}{3}$ inch.

At this stage the little fish begins to feed, and the particles it takes are necessarily very small: the food consists of the minute microscopic larvæ of shell-fish, worms, and other creatures with which the sea teems. It is interesting to observe in the aquarium that these little fish larvæ, minute and delicate as they are, peck at each particle of food in a deliberate and determined manner, and that their food is not carried into them automatically. They see each particle before they seize it, and snap at it by curving the tail into the shape of an S, and then suddenly straightening it. It is however very difficult to rear them completely in confinement, and the successive stages of the various kinds of fish have to be patiently and laboriously traced by comparing specimens caught by fine nets in the sea.

The great and important change which takes place in the larvæ after they begin to feed is the development of the bones of the skeleton, connected with which is the formation of the permanent fins. During this further development considerable changes of form and habit take place, which are different in different kinds of fish. The fin-rays are bony rods and develop at the same time as the rest of the skeleton, and, the fish being in most cases still very transparent when alive, the changes that take place can be plainly seen.

The transformation of the larva with its continuous fin-membrane, after the absorption of the yolk, into the young cod with its three dorsal and two ventral fins is illustrated in Figs. 56–58.

At the later stages of the transformation the little fish ceases to be transparent, its flesh becomes thicker and denser, and the skin becomes pigmented or silvery, and finally the scales, if there are any, or other minor peculiarities of the perfect fish, are developed. For the details of these changes in various species, so far as they have been studied, reference must be made to the figures and descriptions of particular fishes given in the second part of this work. One or two special cases may be mentioned here. The young herring in its intermediate stages is remarkable for its great elongation and slender form, and its dorsal fin is situated towards the tail, much further back than in the fully developed fish. The most surprising transformation is that of the flat-fishes (Figs. 59–62), the larvæ of which swim upright and are very similar to the larvæ of the cod or other fishes of the cod family. When the fin-rays develop in these fishes their exceptional character is at once shown by the extension of the dorsal and ventral fins along nearly the whole length of the dorsal and ventral edges, and by the great breadth and thinness which the body acquires. But during this part of the development a most remarkable change occurs: the eyes are at first opposite to each other, one on each side of the head, as in cod, mackerel, or other fish, but when the fin-rays develop one of the

FIG. 59.

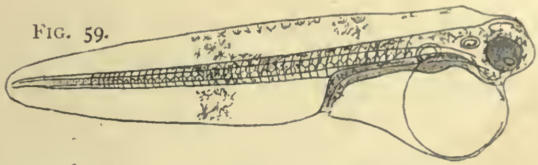


FIG. 60.

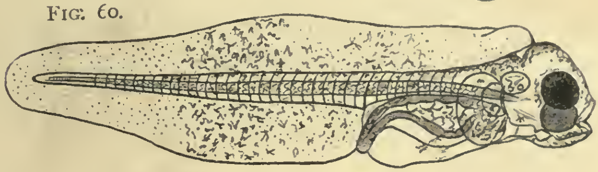


FIG. 61.

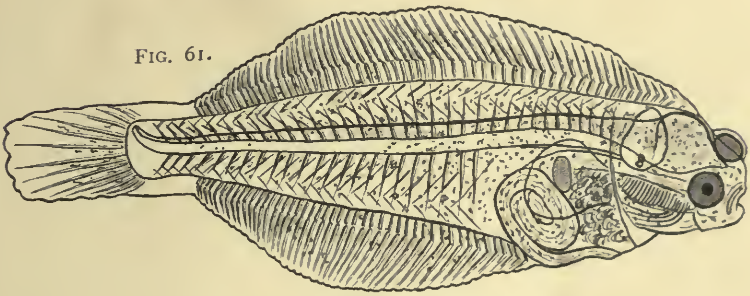
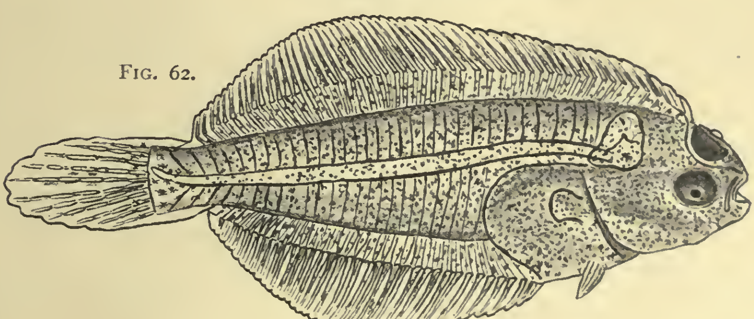


FIG. 62.



FIGS. 59-62.—Four stages in the transformation of the Flounder. Fig. 59, the larva, $\frac{15}{100}$ inch long, two days after hatching; the yolk not yet all absorbed. Fig. 60, the same six days after hatching; the yolk all absorbed, and the mouth open; $\frac{16}{100}$ inch in length. Fig. 61, specimen in a transition stage, with the left eye near the edge of the head: length $\frac{40}{100}$ inch. Fig. 62, specimen in which the transformation is nearly complete; the left eye on the edge of the head; same length.

eyes, in plaice and others the left, in turbot and others the right, moves out of its first position, rises first to the edge of the head, and then passes on to the same side as the other eye. It is in this way that these fishes come to have two eyes on the upper side of the head, and the change takes place at about the time when the little fish abandons the habit of swimming freely in the water and takes to lying on the ground. The most important or final changes in the transformation of the larval fish take place when it is between two and three months old, and although the fish at three months old may still differ in certain details from those which are older it is generally perfectly recognisable as belonging to its particular kind.

CHAPTER V

GROWTH, MIGRATIONS, FOOD AND HABITS

Growth.—A considerable amount of evidence has been collected bearing upon the question of the growth of fishes. When the fish has passed through the two stages already considered, the development in the egg and the transformation into the perfect form, it enters upon the third stage of its life, its adolescence, which extends to the time when it becomes sexually mature and begins to breed. It is important to know how large and how old each kind of fish is when it spawns for the first time, and some of the fundamental facts bearing on these questions are not difficult to ascertain. It is obvious and certain that if every individual fish that survived began to breed when it was a year old, in other words spawned the year after it was hatched, then there would be no immature fish in the spawning season, all would be spawning or about to spawn. We know, however, that this is not the case. If we take the trouble to find out the condition of a large number of any kind of fish at the beginning of the spawning season, we find that many of the larger individuals are spawning, but a large number of smaller can be and are caught which show no signs of becoming ripe, which are evidently immature. The youngest of these fish cannot be much less than a year old, they must have been hatched in a preceding spawning season, although some of them may be more than one year old. This first fact is therefore firmly established, that all the fish of one kind do not spawn when a year old.

Before proceeding further with the subject of age it will be convenient to consider that of size. A great deal of attention has been drawn to the question of the sizes at which fishes of different kinds begin to spawn, or, as it is usually expressed, become mature. There has been a great agitation on the subject of the destruction of immature fish, and various investigations have been made with the object of ascertaining the size at which maturity is attained. Different methods have been employed by different investigators of the question. The simplest method, which was first employed by Dr. Fulton, was to ascertain the length of the smallest mature, *i.e.* ripe or nearly ripe, fish captured. From the investigation in connection with which this method was used very extensive information was obtained about the depths and regions where fish of particular sizes were to be found. But further investigation of the relation between size and maturity was required. In his report on the Irish Survey Mr. Holt gave the smallest sizes of ripe or nearly ripe males and females, and in most cases the minimum was considerably lower for the male, as might be supposed, considering that the average size of the males is in many species smaller. But there is another question, namely, the largest size of the immature, for it is found that some fish which are ripe are smaller than others which show no signs of spawning. The solution of this question involves a careful examination of the roe and milt for the purpose of ascertaining how to make sure that a fish is immature, and out of this another question has arisen, namely, may not a fish after spawning return to a condition in which it is impossible to distinguish it from the immature?

Provided the examination is made at a time of year when there are no shotten fish of the species considered, when spawning has scarcely begun, there can be no possibility of confusing immature and shotten fish. In the plaice, the species to which most attention has been given in this connection, the roe in its immature state is small. It is triangular in shape, and extends back only a short distance between the flesh and the bones behind the belly cavity. A portion of its substance examined with the microscope shows only minute transparent eggs which have no yolk in them. In a spent fish, one which has just finished spawning, the roe is much larger and has thin flaccid walls. A few ripe eggs are usually found in the cavity of the roe, and its substance examined under the microscope shows besides transparent eggs a few with yolk. But it is certain that in the plaice the roe soon diminishes in size after spawning, and returns to a condition in which it is difficult if not impossible to distinguish it from an immature roe. The plaice and certain other fishes are rapid spawners, and therefore shotten fish begin to be seen early in the spawning season, and may be confused with immature before the end of it. In the sole and other species which spawn slowly there is little danger of confusion if the examination be made in the earlier part of the spawning season.

At Grimsby it was found that the smallest mature females, of plaice caught in the northern part of the North Sea, were 13 inches long, the largest immature not quite 18 inches. Of males the smallest mature were 9 inches long with the exception of one at 6 inches, and the largest immature not quite 16 inches. At Plymouth the corresponding limits were 9 inches and 15 inches for female plaice, 9 inches and 12 inches for males. It is thus evident that the plaice in the western part of the Channel attain to maturity at a smaller size than in the North Sea, and the fact that the average or usual sizes in the Channel are also smaller indicates that the cause of the difference is not an earlier or precocious maturity, but a permanent inferiority in size. It has been shown that the smaller or Channel race of plaice extends northwards from the Straits of Dover along the Dutch coast, a considerable proportion of mature specimens being found between 9 and 14 inches among the plaice caught on the Brown Ridges, from thirty to fifty miles off the Dutch coast a little to the south of the Texel. On the other hand the small plaice taken on the Continental coasts in the neighbourhood of Heligoland do not belong to the smaller race, none of the females being mature below the length of 13 inches.

The smallest mature female sole is 10½ inches, the largest immature 12 inches, the average 11 inches; the average for the males being 9 or 10 inches. The haddock begins to spawn at 11 to 16 inches in the female sex, 11 inches in the male. The size of the cod at maturity is of course greater, namely, 22 to 35 inches in both sexes. It is unnecessary to give further particulars here, they will be found in the separate histories of the different species.

We have seen that the immature fish may be a year old, we have now to consider whether some individuals spawn when only one year while others are immature, or whether all or only some spawn at two years. In the case of some fishes whose movements are restricted, which live in estuaries or rivers, it is possible to follow with considerable certainty the history and growth of the fry derived from a certain spawning season, and so discover their condition at successive ages. But in most cases it is found that after the first year the sizes vary so much that the largest one year old cannot be distinguished with certainty from the smallest two years old. Observations on fish of known age in captivity are more certain, and must be instructive, although they are open to the objection that the growth and history may be altered by the unnatural conditions. The flounder however is a fish which bears confinement well, and an experiment was made with a number of these at Plymouth. The young flounders towards the end of their transformation approach the shore and enter bays and estuaries, and in some places are found in April and May in thousands in the pools left by the ebb-tide. Between two hundred and three hundred of these were obtained from Mevagissey in May 1890, and reared in the Plymouth Aquarium. They were ½ inch long and were about two months old. In April 1891, having been fed regularly but not very liberally, the largest was 7½ inches long, the smallest not quite 2 inches. None of these specimens showed any signs of spawning during the season of 1891. The difference in size among them is remarkable enough, but we have good evidence that the same variation occurs under natural conditions in the sea. Plaice in small numbers from 1¾ to 3½ inches long are taken in January, February, and March in the Humber, and flounders from 2½ to 4½ inches in April. These must have been hatched the previous season, so that it is clear that growth in the sea may be as slow as the slowest in the aquarium, and may also be probably as rapid as the fastest in the latter. The cause of the difference appears to be, first, competition for food, secondly, the dependence of growth on the amount of food taken. If each fish were fed separately the growth would probably be nearly uniform. But where there are a large number, as in the sea or the tank, and a limited supply of food, some get a start, and, having once become a little larger, the more they surpass their companions the better able they are to beat them in the competition or search for food. It is reasonable to conclude from these facts that no flounders spawn when one year of age, and the evidence goes to show that the same holds true for other flat-fishes and for sea-fishes generally.

The flounders above mentioned were kept a second year and examined again in February and March 1892, when they were two years old. There were 89 surviving, and they varied in length from 3 inches to 10½ inches. Twelve of them were ripe males 6·4 to 9·2 inches long, and four were ripe females 8·4 to 10·5 inches. The rest showed no signs of spawning. It is remarkable that the smallest ripe specimens were very nearly the same size as the smallest ripe specimens taken at sea, namely, 6 inches for males, 7 inches for females, a clear proof that the results were not entirely altered in consequence of the confinement of the fish. The largest immature fish was 9·7 inches long. It may be inferred from this that some fish of a species may spawn for the first time when two years old, while the majority are still immature.

At the end of three years the flounders which were immature at two years old were examined, and were found to range from 5 to 11½ inches, but they were not examined till May, when those which had been ripe had spawned, and only two females were still spawning. It is probable that few if any flat fishes are still immature at three years of age.

Observations on fishes of different sizes taken at different seasons, which are detailed in the accounts given of the separate species, tend to show that the conclusions reached with regard to flat fishes apply to the majority of other kinds. It has already been mentioned that at the season when the mature fish are spawning large numbers of smaller fish can be captured which show no signs of becoming ripe, which are certainly sexually immature. Broadly speaking, these are one-year-old and two-year-old fish, while a few of the spawners are two years old, but the majority are three years and upwards. On the other hand, where a large number of fish of about the same size are taken together, it is often possible to conclude that they are of the same age, and to estimate that age with great probability. Thus in 1894 I saw a very large number of soles, plaice, lemon dabs, and common dabs taken by the shrimp trawl in the Wallet off the coast of Essex. The soles and lemon dabs were nearly all from 3 to 5 inches long, and as the observation was made in June it could be inferred with practical certainty that they were fish hatched in the previous year. Again, the sardines, which form the object of a regular summer fishery on the west coast of France, are certainly for the most part one-year-old fish of the same species as the pilchard.

There is reason to believe that many fish, chiefly those which live near shore in shallow water, do not grow much in the coldest season of winter, but exact observations on this question have not been made. The conclusions above indicated concerning sea-fishes agree closely with those reached long before by observations and experiments on the salmon. The young salmon remain in rivers the first year of their life as parr. At the second spring when one year old some of them become silvery and descend to the sea as smolts, returning the next autumn as grilse which spawn. These grilse are therefore nearly two years old, but many parr do not become smolts till they are two years old, and therefore do not spawn until the third season after they were hatched.

Migrations.—The next points of interest concerning young fish are the character of the localities in which they are found, their distribution, as it is called, and their movements. The young of certain kinds are found chiefly at the mouths of estuaries and in very shallow water from the edge of the shore to ten fathoms. The plaice is the most important of these. The young plaice almost as soon as they have finished their transformation seek the shore and the shallows, and in many places, where the shore is flat and sandy, they are found in multitudes. Young flounders also seek the shore, but are usually found in greater numbers in the higher parts of estuaries than on the shore of the open sea. Common dabs are found with the young plaice, and also soles, turbot, and brill. Of round fishes the two kinds most abundant in the shallows are cod and whiting, especially the latter. Large numbers of all these kinds are taken in the nets employed for the capture of shrimps. At Cleethorpes, at the mouth of the Humber, shove-nets worked by hand by fishermen wading in the water at low tide are used in shrimping. In these nets at the end of April hundreds of small plaice, from $1\frac{1}{2}$ to $2\frac{1}{4}$ inches long, are taken at one ebb-tide, and, considering what has been shown by experiment to be the growth of the flounder, it is impossible to doubt that these fish are the earliest young brood of the season, hatched the previous January. Plaice of similar size are also taken in June, and even later, but they become less numerous towards the end of summer. Older fish, those of previous seasons, but immature, are also taken, but these are more abundant in somewhat deeper water where they are captured by the shrimp trawl worked from a boat. The soles taken in the shove-nets from April to June are the smallest of the brood of the previous season; they are $2\frac{1}{2}$ inches long and upwards, and are taken only in small numbers. The newly transformed little soles have been taken in the tide pools at Mevagissey in May, and on the Newcome Sand off Lowestoft I have seen hundreds of specimens taken in September which measured 2 inches to $2\frac{1}{2}$ inches long, and which were evidently three or four months old. At Plymouth and other places young turbot are found in considerable numbers swimming at the surface of the water in the later stages of transformation in July and August, brill in May and June. At these stages, before the lower eye has reached its final position, these fish are of considerable size, $\frac{3}{4}$ to $1\frac{1}{2}$ inches in length, and differ from the corresponding stages of other flatfishes also in being opaque and coloured, and swimming constantly at the surface, as they are able to do by means of the large air-bladder which they possess at this period of their lives. But during the next period of their growth, the first six months after they have taken to the ground, they have not been taken in numbers by naturalists, though in all probability living near the margin of the sea. A few are taken in the shrimp nets in the spring of the year after they are hatched, $3\frac{1}{2}$ inches long and upwards; these are about nine months old.

Whiting are taken in most localities where shrimping is carried on, in enormous numbers in the autumn after they are hatched, when they are from a little less than 3 inches to 5 inches in length. But both whiting and cod for the first few months of life, although living near the shore, are found chiefly near the surface, the cod and also the haddock and whiting having the habit at this stage of lurking beneath the bells of large jelly fishes, and feeding on the surface crustacea.

In illustration of the comparative abundance of the different kinds of young fishes taken on shrimping grounds, details of a few catches are here given. In one shove-net at Cleethorpes in one tide on April 25, 1892, were taken with four quarts of shrimps the following fish:—

Plaice	896	$1\frac{1}{2}$ to $4\frac{1}{2}$ inches.
	12	$4\frac{3}{4}$ to 9 ,,
Dabs	3	$1\frac{1}{4}$ to $1\frac{3}{4}$,,

Flounders	6......... ...	$2\frac{1}{2}$ to $4\frac{7}{8}$ inches
	3......	9 ,,
Turbot..............	1........	$3\frac{1}{4}$,,
Brill.............. ...	2..............	$3\frac{5}{8}$ to $4\frac{3}{4}$,,
Soles	4..............	$2\frac{3}{8}$ to $3\frac{1}{4}$,,
Smelts.....	5..............	$3\frac{1}{2}$ to $3\frac{7}{8}$,,
	1..............	$6\frac{1}{2}$,,

A few Sand-eels, Pipe-fishes, Dragonets, Gobies, and Sticklebacks.

On September 27, 1893, with a 21-foot beam shrimp-trawl, after a haul of $1\frac{1}{2}$ hours outside the mouth of the Mersey, with 32 quarts of shrimps were taken :—

12 Soles	all of small size, 7000 of the plaice so small as to pass through the meshes of an ordinary shrimp riddle.
10,407 Plaice	
375 Dabs	
169 Whiting ...	
69 Codling ...	

The older fish are found at somewhat greater depths and distances from shore. As far as our present knowledge goes, it appears that immature fish of the kinds here considered are taken in considerable proportions on all grounds, and therefore at all depths to which the species extend. Mr. Holt estimates that a box of large North Sea plaice contains about 30 per cent. of immature individuals. But the proportion below 13 inches is small, and therefore we may conclude that there are very few one-year-old fish, or fish in their second year, on the off-shore grounds. The ordinary fair-sized fish are thus two years old and upwards. The one-year-old fish are found on the shallower inshore grounds where they are chiefly sought by small vessels which either fish specially for them or take them with shrimps in shrimp trawls. Such fish are chiefly found at depths between two and fifteen fathoms. In certain places where the slope of the ground seawards is very gradual the small fish are in great abundance, and the capture of them in very large numbers has drawn attention to these grounds, so that they have been carefully studied. The most widely known instance of this is afforded by the eastern grounds of the North Sea, extending along the Dutch and German coasts from the Texel to the Horn Reef. Examination of these shallow grounds north of Heligoland in 1895, between the depths of seven and thirteen fathoms, showed that the fish taken by the deep-sea trawl on them were as follows. The plaice ranged from 5 inches to 16 inches in length, so that the proportion of mature fish was small. Of course they were not all one-year-old fish between these sizes, but one-year-old and two-year-old mixed. A considerable number of mature soles were taken, but none under nine inches in length. The one-year-old soles doubtless escape through the meshes of the large trawl. The smallest brill taken was 8 inches long, the smallest turbot 8½ inches, but there were a considerable number of large mature fish of these two kinds, as well as many immature. It would appear that the yearling turbot and brill are for the most part nearer shore than the grounds here in question. Haddocks were scarce on these grounds, dabs of all sizes were abundant. An important fact is that considerable numbers of large mature specimens of the latchet or tub (*Trigla hirundo*), a species of gurnard chiefly found in southern waters, and common in the English Channel, were taken. This was in June. There were also a few grey gurnard and red gurnard, and numerous whiting.

The flat-fishes whose young are found in deeper water are the lemon dab ("lemon sole"), witch, megrim, long rough dab, and thickback. The newly transformed lemon dabs seem to seek water rather deeper than that inhabited by their parents. In the Irish Survey only two less than 2 inches long were obtained, and they were taken at 60 and 80 fathoms. The yearling lemon dabs have however been found in shallow water, in the Wallet, as already mentioned, and in the estuary of the Humber. Specimens of the witch under 2 inches long were taken on the west coast of Ireland at from 70 to 80 fathoms, and of the megrim at the same depth. The long rough dab also at less than 2 inches was taken at 50 to 80 fathoms.

Among round fishes haddock for the first year of their life are not found in shallow water or very near shore. In July and August Mr. Holt obtained a considerable number from 3 to 5 inches long on the Great Fisher Bank and in more southern parts of the North Sea at depths of 16 to 30 fathoms. Three inches appears to be the size at which the haddock begins to feed on or near the bottom. Off the east coast of Scotland Dr. Fulton found young haddock most abundant at 25 to 30 fathoms.

A more precise and comprehensive method of investigating the history of fishes in their natural condition has recently been suggested and applied by Dr. Petersen in Denmark. This method consists in measuring each individual of all the fish that can be collected of a particular species, taking care to collect samples of all sizes and from every different region it inhabits at different stages of its growth. It will then be found that the individuals group themselves in largest numbers about certain lengths, while there are comparatively fewer of the intermediate lengths. The groups of which the members thus approximate to certain lengths are the products of successive spawning seasons, and when the lengths and numbers are registered in the form of curves the whole growth and development of the species is exhibited. We have seen that the shoals of young fish derived from the preceding season can often be recognised, and also sometimes those which are in their second year. The statistical method not only gives more precise information about these, but enables us to distinguish the two-year-old and three-year-old fish. When the condition of the fish with regard to spawning is also registered, we see at what age and size maturity is attained. The full application of this method is work for the future, since it obviously involves considerable labour: to apply it properly the collections for a single investigation ought to be made within a brief period, as otherwise the measurements are not comparable.[1]

The migrations of adult fishes depend principally on three causes or conditions—the development of the breeding organs, the need for food, and the season of the year: most fishes have their customary breeding grounds, feeding grounds, and winter and summer quarters. With regard to the herrings their visits to their spawning beds are very regular, the same beds are visited annually for centuries or longer. But although the movements and positions of the young at successive stages have been followed with some success we cannot say with much certainty where are the adults in the intervals between the spawning periods. They are taken occasionally in small numbers in these intervals, and in all probability retire to some distance from land. If we consider the multitudes of herrings in the North Sea in summer from July to November, it seems certain that they cannot remain there from November to July without being caught; the winter herring are not the same, and we must there-

[1] See *Fourth Report of the Danish Biological Station*, 1893.

fore conclude that the summer fish retreat towards the open ocean.

Mackerel and pilchards, which have no fixed spawning grounds, do not make such extensive migrations, and are not entirely beyond the reach of observation at any time of the year. The mackerel in the Channel comes nearer the coast in summer and is found spawning in May and June up to about five or ten miles from land, but it does not enter bays in pursuit of young sprats until after the spawning season in August and September. In winter it retires from the coast. The pilchard, on the other hand, retires from the coast at the spawning season, and is found, when spawning, chiefly from thirty to fifty miles off. It remains on the coast in winter.

An interesting subject, whose study is far from having been exhausted, is the extension of southern or Channel fish along the Continental coast into the North Sea. The anchovy is found in considerable numbers in the Channel in winter from October or November onwards. Although a regular fishery for it has not yet been established on the English coast, it is taken regularly in small numbers in drift nets or seines used for sprats, pilchards, or mackerel on the coasts of Devon and Cornwall, and has been in some years taken in considerable numbers in the Straits of Dover in November. There is a regular fishery for it annually in the Zuyder Zee and the Schelde, in May, June, and July. It seems certain, therefore, that the anchovies, which in the Dutch estuaries spawn in summer, retreat in winter through the English Channel. In a somewhat similar way the mackerel enters the narrower southern part of the North Sea through the Straits of Dover in summer, and supplies a regular annual fishery off the coasts of Norfolk and Suffolk. Off Lowestoft mackerel are caught in May and June, and again in September, October, and the beginning of November. Perhaps in the intervening months, July and August, they go further north along the Continental coast, and the autumn fishing corresponds to their returning migration. Thirdly, the tub or latchet (*Trigla hirundo*), which is a constant inhabitant off Plymouth, is taken on the eastern grounds of the North Sea near Heligoland in June, and off the Dutch coast opposite Lowestoft in September. It probably is found in these regions all the summer, but I am not certain whether it retreats to the Channel in winter.

Some ground fishes come nearer the coast to spawn while others go further off. Cod are among the former; they spawn in March and April, and the adults when feeding are for the most part on deeper and more distant grounds at other seasons of the year. Haddock and whiting do not make any obvious migration at the spawning season; the haddock is found in spawning condition from 30 to 150 fathoms, the whiting from 10 to 40. With regard to the shallow water flat-fishes, we have seen that mature soles, turbot, and brill are found in summer time in quite shallow water near the coast with the immature. Soles betake themselves to deeper water in winter, and the same thing has been observed of turbot and brill, but the larger adult plaice remain always for the most part in the deeper water.

Food and Habits.—Among quadrupeds and birds there are some which live entirely on a vegetarian diet, and others which take their vegetable nourishment at second hand by preying upon the herbivorous species. Among fishes there are very few kinds which take any vegetable food at all. There is however an interesting distinction between those which prey upon other fishes and those which feed upon the lower orders of marine creatures. But the division is by no means complete; there are some fishes which feed only upon other fishes, and some which do not devour other fishes at all, but there are many which habitually take a mixed diet, including both fish and lower animals. Some of the fishes which prey upon the other fishes, if not all, take cuttle-fishes or squid when they can get them. The angler lives entirely upon fish; the ling, almost entirely; the conger, almost entirely; hake and pollock very rarely eat anything else; whiting, largely; the cod, largely; the coal fish, largely; the dory, entirely; the turbot, brill, and megrim, almost entirely. Other species in whose stomachs other fish are found are the gurnards, the haddock, long rough dab, and also lemon dab, sole, plaice, and common dab. Among the dog-fishes and rays the picked or spiny dog-fish lives entirely on fish, and the other kinds take fish to some extent, except the small spotted dog-fish and the thornback. The mackerel and the shads also prey upon smaller fishes. The habits and modes of obtaining their food are as varied among these predaceous forms as the habits of their victims to which they are adapted. It is necessary, therefore, to consider the habits of the victims first.

The habits of the fishes which feed upon the lower animals again are necessarily related and adapted to the mode of life of these lower animals. The principal different kinds of marine creatures which are not fishes are the Echinoderms, that is to say, starfishes, sea-urchins and the like, Worms, Molluscs, and Crustaceans. In all these classes most of the larger kinds live on the sea-bottom, and have no powers of swimming, or very insignificant powers. The most important exception to this general rule is formed by the squids and cuttle-fishes, which are swimming molluscs with reduced shells. The echinoderms, or spiny-skinned animals, usually remain exposed on the surface of the ground, but many of the worms, molluscs, and crustaceans conceal themselves as much as possible either by burrowing in soft ground, by building tubes or coverings, or by hiding among stones, rocks, or sea-weed. Many of these animals, chiefly among the worms and molluscs, are quite stationary; in the large and abundant class of bivalve molluscs such as the mussel and oyster, scallop, razor-shell, &c., the power of movement is usually extremely limited. All these classes of animals, which inhabit the bottom of the sea in very great numbers, form the food of bottom fishes. The fishes continually seeking these creatures on the ground beneath the water may be compared to the flocks of starlings and other birds which feed upon the worms and insects, snails and slugs on land. Different fishes feed principally on different classes of lower animals, but no kind of fish confines itself exclusively to one class of prey. Thus the haddock and cod feed principally on crustacea, but devour also large numbers of molluscs. The gray gurnard also feeds principally on crustacea, and likewise the large-mouthed long rough dab. The principal food of the plaice is composed of molluscs and worms, the former usually predominating: the sole and lemon dab live chiefly on a diet of worms. In each class of the lower animals there are certain common and abundant forms which are of chief importance as food for the valuable fishes. Among the crustacea the hermit-crabs are devoured in very large numbers. These crabs, as is well known, live in the empty shells of molluscs. There are several species of them differing in size. The largest, the common hermit-crab (Fig. 63) is usually found in shells of the common whelk. The shells are not swallowed by the fish, but the crab is dragged out of its house before being eaten. The common brown shrimp, and the pink shrimp are also largely eaten. The swimming crabs are

FIG. 63.—The Common Hermit Crab, lying beside the whelk-shell which it inhabits.

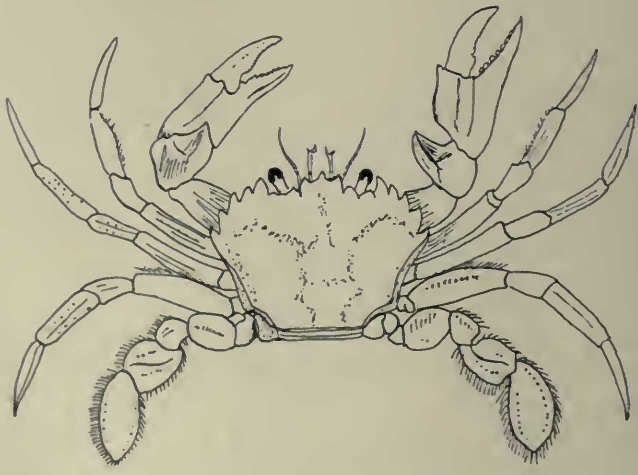


FIG. 64.—A Swimming Crab.

distinguished by the flattening of the hinder pair of legs which they use as paddles, and are thus enabled to sustain themselves for a short time in the water. These are very common in

British seas, and are largely devoured by cod, haddock, and gurnards. One of the commonest kinds is represented in Fig. 64. Fig. 65 shows an example of another class of Crustacea, called the Amphipods, to which the common sand-hoppers belong. They are generally smaller than the crabs. The species figured burrows in soft ground and is common on all our coasts. It is frequently found in the stomachs of haddocks, gurnards, long rough dabs, common dabs, witches, and plaice.

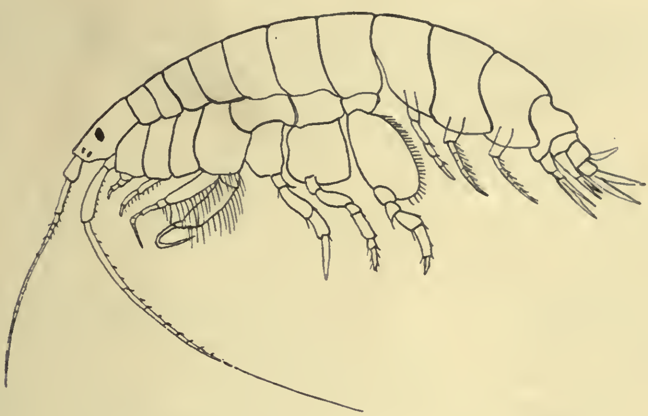


FIG. 65.—Ampelisca, a common marine Amphipod.

In Figs. 66–70 are represented the forms of some of the molluscs most commonly found in the stomachs of fishes. Razor-shells or *Solen*, of which there are several species, are largely eaten by plaice in the Firth of Forth and the North Sea. The smaller specimens are swallowed entire, the shell which is thin being crushed by the teeth in the throat of the fish, but often the stomach is found to contain only the fleshy parts of the shell-fish, commonly called the feet. The *Solen* lives in a vertical position in a hole which it burrows in the sand by means of its "foot," and the latter is therefore turned towards the bottom of the hole. Yet the plaice is able to drag the shell-fish from its burrow, and to seize its "foot" and tear it out of the shell. Figs. 66, 67 represent two different species of razor-shell, the straight form which is represented as seen from the ventral surface, with the lower edges of the shell separated to show the foot, being *Solen siliqua*, the curved form *Solen ensis*. The

66

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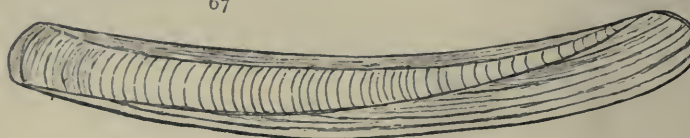

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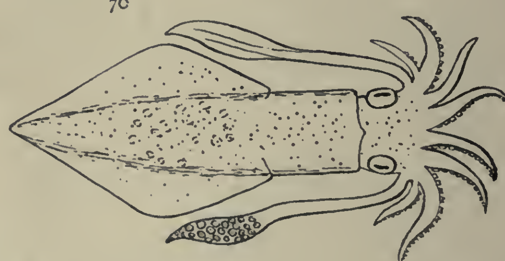


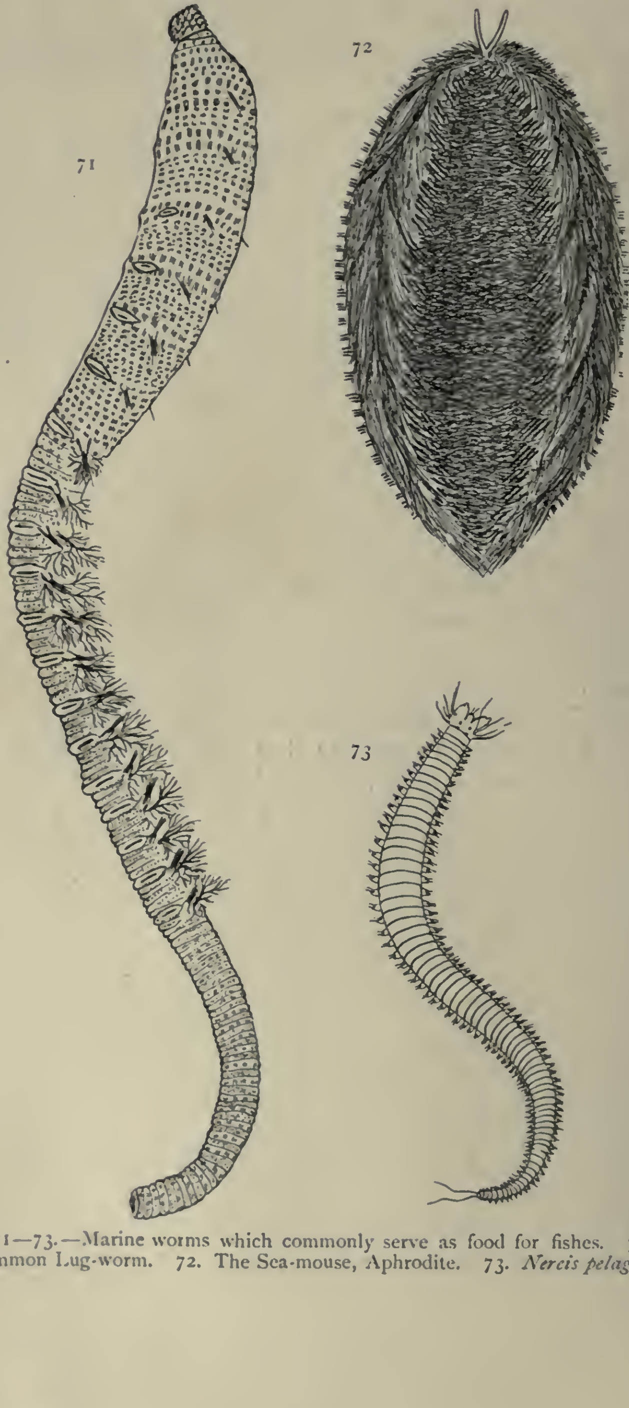
69

FIGS. 66—70.—Molluscs which commonly serve as food for fishes. 66. *Solen siliqua*, a Razor-shell. 67. *Solen ensis*, another kind of Razor-shell. 68. *Mactra subtruncata*, a common bivalve. 69. *Scrobicularia*, a smaller kind of bivalve. 70. The common Squid.

former grows to a length of 8 inches, the latter to 3¾ inches. I found that the small plaice landed at Grimsby in March from grounds off the Sylt Island on the German coast had been feeding almost entirely on *Solen*, and it also forms a considerable part of the food supply of the same fish in the Firth of Forth. The same shell-fish is also found occasionally in the stomachs of other flat-fishes, namely, common dabs, long rough dabs, and even sometimes in lemon dabs. The bivalve represented in Fig. 68 (*Mactra subtruncata*) is eaten by plaice on the Dogger Bank, and in the Firth of Forth, and doubtless in other localities. The small shell-fish shown in Fig. 69 (*Scrobicularia*), of which there are two or three species, forms a large proportion of the food of the plaice in certain localities, such as the Firth of Forth and the Irish Sea. It is also eaten by other flat-fishes, and very largely by the haddock. The common squid (Fig. 70) is a favourite food of the cod, conger, spiny dog-fish, turbot, brill, ling, and other fishes.

We next come to the Annelids or Worms, now usually and more precisely named Chaetopods. The common lug-worm represented in Fig. 71 is well-known from the fact that it inhabits flat muddy shores between tide marks all round our coasts in countless multitudes, but it lives also beyond low-water mark where the ground is sufficiently soft. Fig. 72 represents a creature commonly known as the sea-mouse, but to which naturalists have given the name of the Greek goddess of love and beauty, *Aphrodite*. Notwithstanding its unusual shape and appearance, it is one of the bristle-bearing worms, consisting like the rest of a series of similar segments; but the boundaries of these segments are concealed by a sheet of felted bristles which covers the back. Its beauty consists, not in its rotundity of form or curved outline, but in the iridescent colours of the delicate silky bristles on its sides. In Fig. 73 is shown the appearance of one of the commonest of the numerous species of *Nereis* which live under and between stones, or burrow in soft ground. All these forms, as well as numerous other species of worms, many of which live in fixed tubes of their own manufacture, are largely eaten by plaice, sole, lemon dab, and other flat-fishes. *Aphrodite* is also eaten by cod and haddock, and by the thornback ray, and the spotted dog-fishes.

Among Echinoderms the forms most largely eaten by fishes are those known as sand-stars and brittle-stars. Two of the species most constantly devoured are represented in Figs. 74, 75. The sand-star (*Ophiura albida*), is distinguished by the stiffness of its arms, and the minuteness of the spines which they bear.



FIGS. 71—73.—Marine worms which commonly serve as food for fishes. 71. The Common Lug-worm. 72. The Sea-mouse, Aphrodite. 73. *Nereis pelagica.*

In the other form (*Amphiura filiformis*), the arms are longer, more flexible, and bear longer spines. In others again the spines are much longer and the arms thicker. These are found in the

FIG. 74.

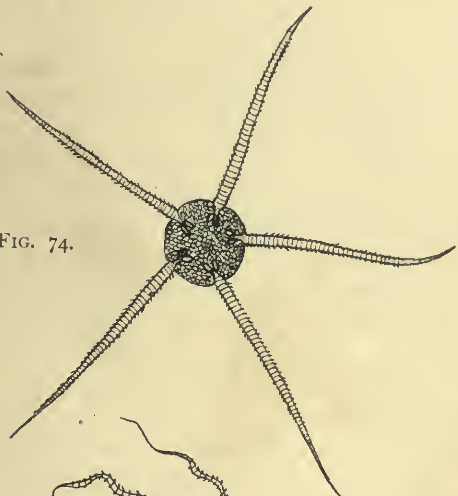


FIG. 75.

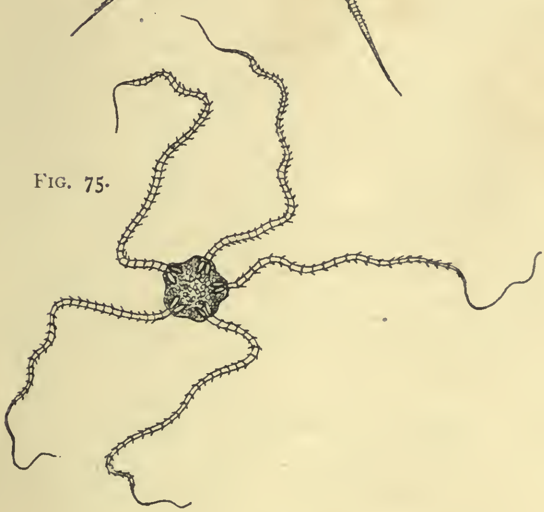
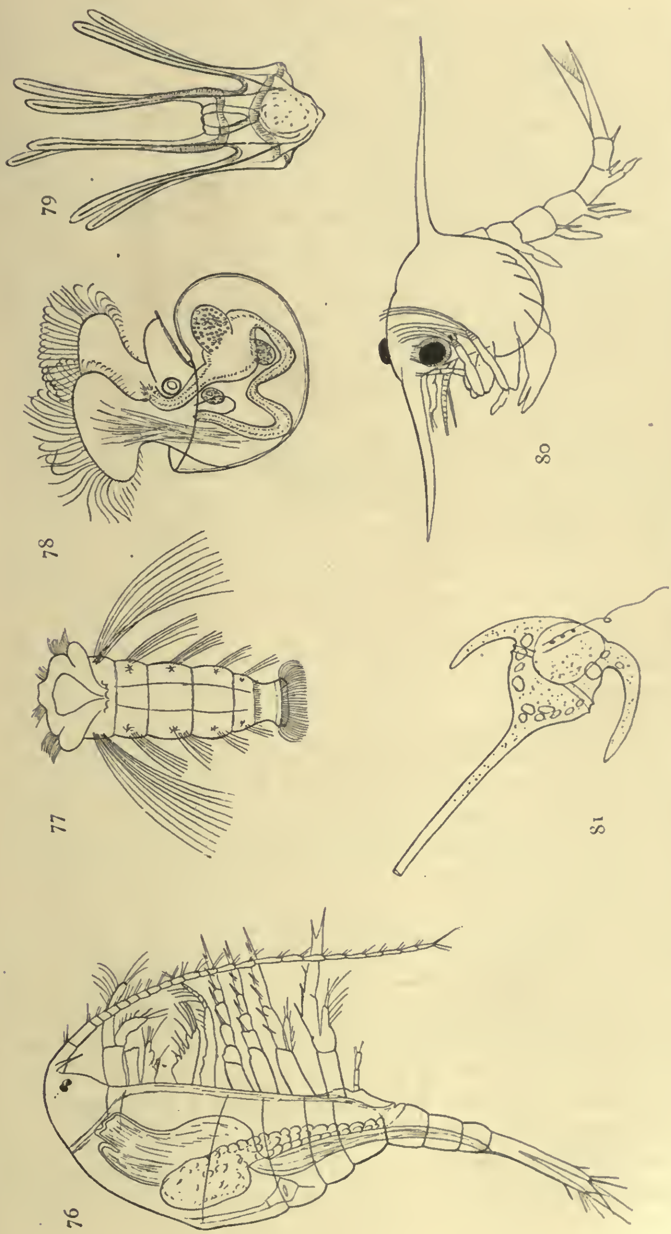


FIG. 74.—A Sand-star (*Ophiura albida*).
FIG. 75—A Brittle-star (*Amphiura filiformis*).

stomachs of plaice, sole, lemon dab, common dab, long rough dab witch and haddock, but in the case of the plaice, lemon dab, and witch, only in a small percentage of individuals; they are most regularly eaten and in greatest numbers by the haddock and long rough dab. Common star-fishes are occasionally swallowed by the haddock and long rough dab but, as might be expected, the strong-spined sea-urchins do not serve as food for fishes to any great extent; some of the softer-shelled forms with weaker spines (*Spatangus*, *Amphidotus*) are however occasionally eaten.

But there are fishes which feed neither on the ground animals nor on other fishes, namely, those which feed on the lower animals that swim in the water. In other words, the water has a population of lower animals as well as the ground under the water, and this population supports different kinds of fishes. The swimming animals now to be considered are all small, very small, or extremely minute, but they make up by their numbers for their small size, and consequently the amount of substance contained suspended in the water of the sea is enormous, and forms a very large supply of available food. This floating population of the water consists partly of permanent elements, partly of temporary, that is to say, partly of animals which live their whole lives in this condition, partly of the minute young (larvæ) of nearly all the animals that in their adult condition live on the bottom. The chief class among the permanent inhabitants is that of the copepods, a particular division of the crustaceans, ranging in size from ¼ inch downwards. These animals are constantly and everywhere abundant, and their bodies are rich in oil and extremely nutritious. With these there are swarms of the larvæ of larger crustaceans, worms, molluscs, and echinoderms, which succeed one another according to the breeding seasons of their parents, and are most abundant in summer. All these together form the food of the teeming shoals of surface or mid-water fish, namely, the herring, pilchard, and sprat. The mackerel feeds by preference on young sprats or other young fish which swim near the surface, but appears to depend on the same kind of food as the herring at certain times.

Some examples of the numerous different minute forms which live suspended in the water of the sea are represented in Figs. 76–81. The copepod, shown in Fig. 76, is one of the largest and most abundant in the North Sea and on other parts of our coasts. Fig. 80 represents a stage in the development of a common swimming crab (*Portunus*). The actual length of a



FIGS. 76–81.—Some examples of minute pelagic animals. 76. *Calanus finmarchicus*, a common Copepod. 77. Larva of a tube-forming Worm (*Leucodore*). 78. Larva of a shell-less Mollusc (nudibranchiate species). 79. Larva of a Sea-urchin. 80. Larva of a Swimming Crab. 81. A plant-like organism (*Ceratium tripos*).

larva of this kind would be about $\frac{1}{8}$ inch. It is remarkable for the length of the spines which project forwards and backwards from the head region, and for the length and size of the tail, which in the fully developed crab is rudimentary. Fig. 77 represents a larva of one of the tube-inhabiting worms; among the features by which this form is distinguished is the great length of its bristles. Fig. 78 shows the structure and appearance of a mollusc larva; in this case the larva of one of the shell-less or nudibranchiate forms. The larva however is provided with a shell into which it can withdraw itself, and with an operculum with which it can close the aperture. It sustains and propels itself by means of the long vibratory processes or cilia on the edge of the lobes which protrude from the shell. In Fig. 79 is represented the larva of one of the echinoderm class, namely a sea-urchin. One chief peculiarity of this larva is the presence of eight very long arm-like projections, each of which is supported by a calcified rod. It will be understood that to the unaided vision such creatures as those figured appear in a glass vessel of sea-water merely as moving specks, and that the figures represent them as seen under the microscope.

A complete account of the animals which serve as food for fishes would embrace nearly the whole of marine zoology, and indeed a thorough knowledge of the subject including the particular forms on which each kind of fish depends in its early stages, and in the different regions it visits, and the mutual dependence of the various animals in the sea is not yet available, but has to be obtained by further investigation of the most minute and extensive kind. One more interesting form however may be mentioned here.

Its shape and appearance are represented in Fig. 82. It belongs to the same division of crustacea as the opossum shrimps, which differ from the common shrimp in having usually eight pairs of long anterior (thoracic) legs, each of which forks into two branches. This particular species and its nearest relations have the remarkable power of giving out light, a property which does not belong to the whole body but is localised in ten special rounded organs, four in a single row on the abdomen, two pairs on the bases of the anterior limbs, and one on each eye-stalk.

In its younger and smaller stage this luminous shrimp has been taken in numbers at the surface of the sea, in the North Sea, in the Firth of Clyde, and off the coast of Cornwall. But in the adult condition it has only been taken at considerable depths ; it is then about $1\frac{1}{2}$ inches long. It does not, however, when adult crawl upon the bottom ; it is a restless swimmer and requires no support, but is only found near the bottom. This animal is a constant inhabitant of certain deep gullies in the Firth of Clyde, where the depth is about 70 fathoms, and where it can always be captured in some numbers by towing a shrimp trawl at considerable speed. Recent observations have shown that Loch Fyne

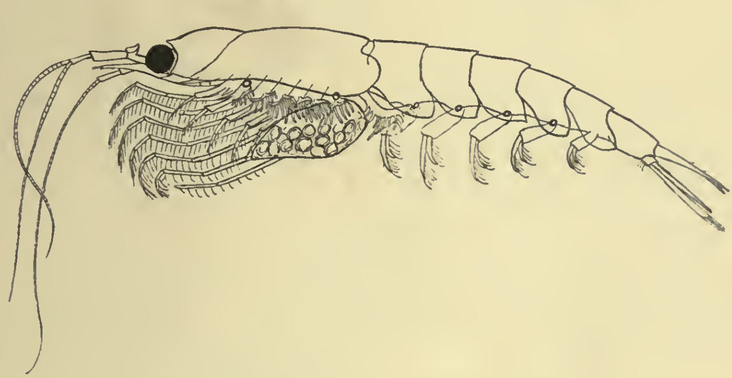


FIG. 82.—A luminous Shrimp (*Nyctiphanes*) ; after G. O. Sars.

herring feed largely on this crustacean, a fact which proves that herring may descend to considerable depths.

It is a well-known story that some Hindoo religion taught that the world rested upon the back of a great elephant, and the elephant stood on the back of a huge tortoise, and that when an inquiring student asked what the tortoise stood on, he was severely punished for his irreverent audacity. In the case of fishes we have seen that some feed on other fishes, and these on lower animals, and now follows the question—What do the lower animals feed on ? Fishermen are apt to solve such difficulties by the statement that these creatures live on suction, which is in many cases perfectly true ; but what is the substance sucked in ? We know that the original source of all food is the vegetable kingdom, which is able to build up its substance from the air and soil and water with the help of the sunlight. So it is in the sea. Creatures may prey upon other creatures, but in the last result they depend upon the vegetable kingdom. The elucidation in detail of the mode in which this is effected still offers an interesting field of study. We know that large numbers of univalve shell-fish, such as the periwinkle, graze on the fields of sea-weed which fringe the shores, and that these shell-fish are eaten by fishes. But it is certain that the chief supply of plant food in the sea consists of very minute microscopic plants. These exist constantly in a detached suspended form in the water, and also on the bottom. Then there are exceedingly minute microscopic forms of animal nature that live upon the minute plant-forms. All the bivalve molluscs, which form no inconsiderable portion of the food of fishes, live entirely by the "suction" of these exceedingly minute animals and plants; they are able to draw a current of water constantly through the cavity within the shells, and there this food-dust is strained out and passed into their stomachs. In the upper waters the microscopic plants form the food-basis of all the population.

The variety of form in these plants is remarkable, and their abundance in individuals often so great as to render the water turbid and to colour large areas of the sea. One common form in British seas is a small sphere of a bright green colour. The diatoms are distinguished by their yellowish brown colour, and their indestructible siliceous (flinty) coating. There is another tribe of organisms which appear to live like plants, but have often been placed in the animal kingdom. One of the most characteristic of these is shown in Fig. 81. Unlike those already mentioned, these forms are provided with long vibratile processes or flagella, although these are only seen under favourable conditions. Scarcely any gathering of floating minute organisms can be obtained off our coast without including some specimens of the organism figured (*Ceratium tripos*).

Every kind of fish has its own special way of obtaining its food, to which its habits, senses, and structure are adapted, and the adaptation is often most curious and interesting. The herring, sprat, and pilchard, depending chiefly on minute creatures in small numbers, do not have much need for teeth, and accordingly in them the teeth are small or absent. In these fishes, and in certain others, *e.g.* the basking shark, as mentioned in Chapter II., the length and proximity to one another of the gill-rakers constitute a special apparatus for straining minute organisms from the sea-water. The gill-rakers are stiff horny rods projecting forwards from the inner and front edges of the gill-bars, and in fishes which feed on large animals they are short and far apart, so that the gill-apertures are wide and unobstructed. But in the herring, shad, pilchard, &c., the projections are long and close-set like the teeth of a comb, and thus fill up the whole of the gill-apertures with an efficient straining apparatus (Fig. 83). The fish takes gulps of the water containing crowds of copepods, &c., and passes the water through its gill-rakers

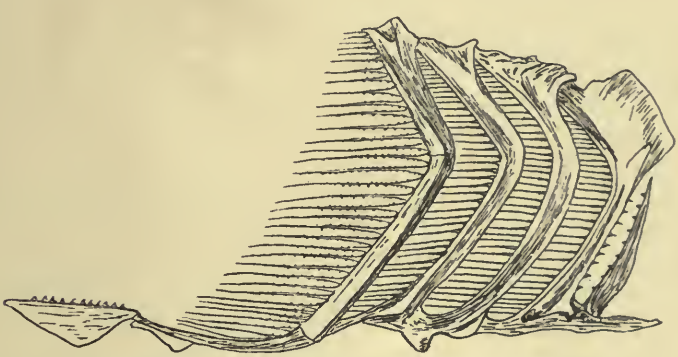


FIG. 83.—The gill-bars and gill-rakers of the Herring, the gill-filaments which are attached to the outer sides of the gill-bars having been removed.

The way in which the sides of the upper jaw are brought to the front of the gape when the mouth is open, is also probably of some advantage in the process of feeding. The mackerel, on the other hand, pursues separately the small fish on which it preys, hunting them by sight; its activity and speed are its special adaptations in addition to its tweezer-like jaws. The fact that mackerel are so easily caught with artificial bait having a shining surface and moving through the water, and that they will bite at almost anything attached to the hook provided that it is moving, shows clearly how they are accustomed to snap at small fish and are guided by their eyes, not by smell, touch, or taste. Fish that thus trust to their sight naturally feed in the daytime, and fishing for them with hook and line must be carried on in the daytime. The whiting is another instance. An upper jaw longer than the lower is generally found in fishes which feed on the ground, and in the fishes of the cod family a barbel on the chin is associated with this condition. The barbel signifies that the sense of touch is called to the aid of that of sight and smell in finding prey, and it carries with it the possibility of feeding in the dark. Thus fishes with barbels may be chiefly nocturnal in their habits; this is the case with the ling and the rocklings, the latter having several barbels. To watch a rockling hunting in the aquarium reminds one forcibly of a dog following a scent, and it is a matter of observation that they remain concealed in daytime, except when induced to come out by the presence of food, if they are hungry, and that they move about freely at night. The fishes of the cod family which feed in the upper waters have usually the lower jaw longer than the upper, and no barbel; as for instance the pollack, but in the hake the jaws are equal in length.

Among the flat-fishes there are some which feed on other fishes, and others which feed on lower animals. The corresponding difference in the jaws is interesting; the fish-eating forms have the mouth large, the jaws strong, and equal on the two sides of the body, with sharp teeth; as in the turbot, brill, megrim, long rough dab, and halibut. In the plaice, dab, lemon dab, and sole, on the other hand, the mouth is small, and the jaws and teeth very feeble on the upper side of the head, strong on the lower side. These fish bite with the lower corner of the mouth. The fish-eating flat-fishes also exemplify the process of obtaining prey by lying in ambush, concealed, instead of pursuing and overtaking it; they lie partly or wholly buried in sand or gravel, with their changeable colouring where it is exposed closely resembling the appearance of the surrounding ground, and when other fish come near enough they rise suddenly and seize them. The other flat-fishes are also well concealed, but the result in their case is escape from enemies, not deception of victims.

The sole is one of the most retiring of fish; its burrowing habits and power of changing its colour to resemble the ground make it almost or quite invisible, and it seldom moves or uncovers itself except at night. In the aquarium this is constantly observed, although it will when hungry feed in the daytime. It is provided with special organs of touch on the lower side of its head, and also has an acute power of smell. It hunts for worms or shrimps by tapping the ground gently with the side of its head. The eyes are only of use to see enemies above it, and although in the aquarium it acquires in time the habit of rising from the ground and taking worms as they fall from above, it finds difficulty in seizing them before they reach the bottom. Yet with all this provision for concealment, of no use in obtaining food, we do not know at present that it is a much persecuted fish. Future examination of the food of predaceous forms, perhaps of skate and angel rays, may show that the sole has as much to fear as its concealment would indicate; it has been found in the stomach of the angler.

The plaice, although it buries itself at times, feeds principally in the daytime and on shell-fish. It has a special crushing mill for these in its throat. Nearly all fishes have teeth in the throat on certain bones belonging to the gill apparatus, and these teeth are usually sharp, but in the plaice they are broad and rounded, and crush shells with great ease. Similar teeth are found in the jaws of the cat-fish, which feeds on crustaceans and shell-fish.

The mode of hunting of the angler and John dory have not yet been mentioned. The former has special provision for concealment and has huge jaws, the lower of which projects beyond the upper. The spines of the first dorsal fin are separate, and can be raised into an upright position on the top of the head, the first having a tag of membrane at the end. The fish lies at the bottom, and other fishes appear to be attracted by this tentacle and fall a prey to the angler. The dory swims upright in mid water, and its body is extremely thin from side to side, so thin that when it is directed towards another fish it does not attract notice or create alarm, and the dory is able gradually to approach within striking distance. A fuller account of these two fishes is given in their special histories.

Among the dog-fishes and skates and rays there are similar differences in the habits and food. The spiny dog-fish is a bold strong swimmer which pursues and devours weaker fishes in the daytime; it persecutes herrings, sprats, mackerel, and whiting, and lives in shoals which are sometimes so large that they seriously interfere with drift-net fishing. The spotted dog-fishes, on the other hand, are nocturnal, and feed chiefly on the lower animals of the ground, especially crustacea. In the aquarium these fish lie still and apparently asleep or half asleep in the daytime and move about at night. They hunt by smell. It seems somewhat surprising that the common or gray skate should feed largely on fish. It is easy to understand that it can feed on bottom fishes, and these do form great part of its food, but pollack, whiting, and mackerel are also found in its stomach, although its shape would appear to be eminently unsuited to their capture.

The food of fishes in their young stages is necessarily different from that of the adults. Mention has already been made of the minute living particles swallowed by the delicate newly-hatched larvæ of bony fishes when living in the open or surface waters. In a successful endeavour to rear larval herring at Kiel it was found that at first they ate the larvæ of small molluscs, and when they grew a little larger, began to take copepods which soon formed their entire food. Copepods also form a large proportion of the food of other young fishes. On the Lancashire coast young plaice $\frac{7}{8}$ inch to $2\frac{7}{8}$ inches long were found to be feeding principally on minute crustacea, and about half of the crustaceans in the stomachs were copepods; the others were young shrimps and sand-hoppers, and part of the food was small bivalves and worms. It was also found in Loch Fyne that cod and coal-fish from $1\frac{1}{4}$ to 3 inches long were feeding almost entirely on copepods.

CHAPTER VI

PRACTICAL METHODS OF INCREASING THE SUPPLY OF FISH

In recent years much attention has been devoted to measures either proposed or actually adopted for maintaining or increasing the supply of the most valuable kinds of fishes. These measures consist either in the prevention of practices on the part of fishermen which involve the destruction of the fish while young and undersized, or in the artificial propagation of the fish. We will consider these two classes of measures in succession.

With regard to the protection of young fish we have to consider not only whether a particular restriction or regulation will increase the supply of adult fish, but how it will affect the fishermen. It may be argued that any improvement in the supply must benefit the fishermen more than any other class of the community, but this is evidently not the case in certain instances. For example, if shrimping is prohibited on account of the destruction of small flat-fishes which it involves, the direct and immediate result to the shrimpers is certainly not profit but loss. In the application of a measure of restriction therefore, even though it appears certain to increase the supply of the most valuable fish, due consideration must be given to its immediate effect on the men engaged in the fishing industries.

Theoretically the protection of young fish is extremely simple; it is certain that if we require the greatest number of fish above a certain size, we should kill none below that size. In dealing with sheep, leaving questions of pasture or accidental death out of consideration, to refrain from killing the lambs is equally simple in practice. But it is not so simple in practice when we are dealing with fish in the sea, because we cannot pick out those of the size we want and leave the rest alive. Another principle equally simple in theory and difficult in practice, is to regard generative maturity rather than size, and to avoid killing any female fish until it has spawned once, the result of which would be that there would always be a large supply of young. In practice then we have to consider how far we can stop the destruction of undersized or sexually immature fish which is involved in actual fishing operations, and here again we find two subdivisions of the subject; namely, first, the destruction of fish of valuable kinds so small as to have no value in the market, and, second, the capture of undersized fish for sale. Clearly a prohibition of sale will only directly affect the latter kind of destruction, though it may indirectly affect the former, in a manner which will be considered presently.

It has been stated in Chapter V. that large numbers of very small plaice, soles, turbot, brill, and whiting are captured in shrimp-nets, both in those worked by hand or by a horse along the shore, and those worked from a boat. Not all of these are necessarily killed, and to a great extent the proportion that are returned to the water alive depends on the carefulness of the fisherman. But as a rule the fisherman is not careful, and the majority it may be safely said are usually killed. The only way to prevent this destruction with certainty is to prohibit the use of the nets in places where the young fish abound. No prohibition of sale will have any effect, because the fish here considered, fish only a few months old, have no value in the market; there is no demand for them as a table delicacy as in the case of whitebait. In some cases they may be used as a manure, but they are not usually sold for that purpose; as a rule they are not used at all but regarded by the shrimpers as refuse of no importance.

As shrimping is carried on entirely or almost entirely within the three-mile limit, its regulation is within the powers of the District Fishery Committees, and nearly all of these have passed bye-laws for the purpose of diminishing the destruction of small fish involved in the capture of shrimps. These bye-laws regulate the size of the net, the size of the mesh, the localities where shrimping may be carried on, and the frequency with which the net must be raised and emptied. In places where shrimping is a considerable industry, as at the mouth of the Thames or Humber, and on the coast of Lancashire, its total prohibition is impossible, and all that can be done is to diminish as far as possible the destruction of small plaice, &c., which it involves. The possibility of taking shrimps by instruments which do not capture flat-fishes has been much considered ; one such instrument is a trap like a lobster-trap, another a trawl with its ground-rope replaced by a bar raised some inches above the bottom.

A certain number of saleable fish are taken in shrimp-trawls, but we have now to consider nets used expressly for the capture of fish. One method of protecting the smaller fish is to prohibit trawling on the inshore grounds. Recently, in accordance with the powers conferred upon them, many of the District Committees have adopted this method, which must of necessity be very effective for the purpose. The difficulty which arises from it is the distress it causes to the fishermen. On the south coast of Devonshire Brixham trawling vessels of small size have long been used for trawling in the bays, and catching small plaice. A bye-law was passed by the local committee prohibiting trawling within certain limits, thus closing not the whole but a portion of the territorial waters under its jurisdiction. The men engaged in this branch of the industry have objected to the law. It may be supposed that these men ultimately reap the benefit of obtaining more large fish outside the prohibited limits, and probably that is the case. But in the meantime they have to fish in regions more exposed to the weather, and get less fish than they did before. The diminution of their earnings and greater labour and exposure does not however amount to distress, and the bye-law appears to be quite justifiable.

It is evident that the measures hitherto mentioned do not affect the capture of small flat-fishes on the eastern grounds in the North Sea, or on other similar grounds beyond territorial limits. The agitation against this destruction arose among the people engaged in the trawling industry itself, and resulted in a demand perseveringly and earnestly put forward for the prohibition of the sale of undersized fish by Act of Parliament. It is generally admitted by those that have most experience of the circumstances connected with the trawling for small plaice off the continental coast, that the prohibited fish if thrown overboard would not usually survive, but that the majority of them would be fatally injured either by pressure in the trawl or by long exposure and rough handling on deck. The argument is that when the small fish were unsaleable the boats would not find it worth while to fish on the grounds in question. If the size limit were made high enough this result would certainly be secured. Mr. Holt is convinced that a limit of thirteen inches for plaice alone would make fishing on the eastern grounds quite unprofitable. This is probably true in the main, but it must be remembered that to the north of Heligoland, and probably in other parts, a considerable number of adult soles, of turbot, and brill of all sizes, and of plaice from 13 inches to 16 inches long are to be found in summer, and even with a limit of 13 inches for plaice some voyages might be made for the sake of these other valuable fish. On the other hand I have shown that a limit of 13 inches would cut off eighty or ninety per cent. of the plaice taken by Lowestoft boats on the Brown Ridges, thirty to fifty miles off the Dutch coast, that a large proportion of female plaice on this ground under 13 inches are mature, and that the limit of 13 inches would close such an extent of grounds to the Lowestoft smacks, that it is doubtful whether they could be kept at work at all. It was previously proved that in the English Channel some females are mature when less than 13 inches long, and that this limit could scarcely be borne by the industry there.

The limits recommended by the Sea Fisheries Protection Association were 12 inches for turbot and brill, 10 inches for plaice and soles, 11 inches for lemon soles. As undersized lemon soles are not known to abound regularly on particular grounds, and are not found on the eastern grounds of the North Sea except in very small numbers, there is no reason to impose a size limit with respect to them at all. The other sizes are certainly reasonable; they would not unduly restrict the area over which deep sea trawlers can work. It may be urged however that 12 inches for turbot and brill is not high enough. These fish are not smaller on the south coast, are so hardy that they would probably survive if care were taken to throw them overboard promptly, are of greatly increased value when large, and lastly are confined when small and young to shallow inshore grounds. The limit of 10 inches for plaice and soles is certainly nearly as high as the industry could bear; it might be raised to 11, but not higher. But, on the other hand, how much good would it effect? The present writer has seen a trawler's crew on the eastern grounds shovel overboard all the plaice under 10 inches, simply because the price for such fish was too low to pay for taking them to market, and at the same time this vessel made a very good voyage out of the large soles, turbot, brill, and larger plaice on the same ground. The limit would not entirely put a stop to fishing on the eastern grounds, but would probably have the effect of saving a great many plaice under the limit. Vessels would not continue to fish in places where few other fish were to be got. The possibility of making up a voyage by filling up the fish hold with small plaice when the price was good would be gone, and for this reason fewer of the small plaice would be caught.

What then is to be said of the limits recommended by the Parliamentary Committee of 1893, namely, 8 inches for plaice and soles, 10 inches for turbot and brill? These limits were embodied in a bill introduced into Parliament in 1895 but not passed, and the National Sea Fisheries Protection Association petitioned for its reintroduction in 1896. As far as deep sea trawling is concerned, such limits would make no appreciable difference at all. It is true that a few plaice under 8 inches, and occasionally a turbot or brill under 10 inches, are taken on the eastern grounds, but the deduction of these from the total catch would make no change in the habits of the trawlers, and confer no protection on the fish. These limits would, however, make some difference to the small inshore trawlers in places where such trawling is still allowed. A certain number of soles under 8 inches are landed by small boats at Lowestoft, and of plaice under that size in the Humber, and the proposed limits would protect these. The landing of turbot and brill under 10 inches for sale seems to be a rare occurrence.

As the circumstances of the trawling industry and the habits of the fish do not appear to admit of the preservation of all plaice, soles, turbot, and brill, not to consider other species at present, until they have spawned once, we have to face the possibility of a continued diminution in the supply of these fish, in spite of all protection of the young, as a consequence of the excessive capture of the mature individuals. The trawling may be so extended and so effective that not enough spawners are left to produce an adequate supply of young. This point appears to have been reached according to the experiments and observations of the Scottish Fishery Board, for in the Firth of Forth and St. Andrew's Bay, notwithstanding the prohibition of trawling in the territorial waters, and the absence of other fishing destructive to young flat-fishes, the number of the latter has not increased. To remedy this state of things artificial propagation has been recommended, and in certain cases adopted. We may here briefly discuss the question how far artificial propagation appears capable of increasing the supply of fish, whether in conjunction with or independently of the protection of the young.

Firstly, it may be pointed out that up to the present time artificial propagation of marine fishes is limited to the production of fry at the stage when the yolk is nearly absorbed, which are then liberated in the sea. From this stage onwards they are no better off than fry which have been hatched under natural conditions. At Arendal, on the south coast of Norway, and at Dildo Island, in Newfoundland, there are two hatcheries almost entirely devoted to the propagation of the cod. In both these cases it is stated, and there is no reason to doubt the statement, that a greatly increased number of fish have been seen and captured in the neighbourhood of the hatcheries as a direct result of the millions of fry liberated. Cod and other fish have been hatched also in hatcheries on the coast of the United States, but not very regularly, and in 1894 the hatchery of the Scottish Fishery Board at Dunbar commenced operations, the latter establishment dealing principally with the plaice. Now it may be admitted that locally an increase in the supply of fish may be produced by the annual liberation of some millions of fry. But we have to consider firstly the proportion between the value of this increased supply and the cost of the hatchery. At present we have not the data necessary for making this comparison, but it should be always remembered that the cost of the hatchery has to be met, not out of the total value of the fish derived from the hatchery, but out of the value of the fish after the cost of catching and marketing has been deducted. The fry having been liberated in the sea, those of them which survive to reach marketable size have to be caught. If we suppose one firm to have the exclusive control of a sea fishery, and to establish a hatchery as a business enterprise, then clearly the question for that firm is whether the resulting increase in the catch of fish is sufficient to pay for the cost of the hatchery and leave a profit. The nation in the actual state of matters is such a firm, and hitherto no attempt has been made to ascertain from reliable and complete data whether the working of a hatchery is commercially profitable or not.

In the meantime we may well take some trouble to consider how far the operations of a hatchery can be profitable, reasoning as accurately as possible from what we know of the facts bearing upon the question. The Scottish Fishery Board calculates that if one in a hundred of the fry distributed from the Dunbar Hatchery in its first two years ultimately came into the market and realised 6*d.* each, the resulting value would be £18,000 ; but the great majority of the fry were plaice, and 3*d.* each is a fair average price for plaice on landing. One in a thousand sold at 1*d.* each would realise about £300. The number of plaice eggs obtained at the Hatchery in 1895 were forty-four millions, and the number of plaice fry liberated 38,615,000. Now we may take the average number of eggs produced by a female plaice to be 200,000, as indicated by the figures given in Chapter III. Therefore the number of eggs above is the produce of 220 female fish. According to statistics collected by Mr. Holt, four million mature female plaice are landed per annum at Grimsby alone. So that for 19,090 spawners killed at Grimsby, the eggs of one are hatched at Dunbar. It may however be supposed that the mortality or destruction in the sea between the shedding of the eggs and the stage of the absorption of the yolk in the larva is greater than in the hatchery. We may suppose that the destruction is nine times as great in the sea, which is certainly more than the actual proportion. In that case one spawner in the hatchery is equal to nine in the sea, or the total result of the work of the hatchery is equivalent to leaving in the sea one mature female out of every 2,000 killed at Grimsby, a proceeding which would clearly not make much difference to the total supply of plaice in the North Sea.

It may be said, however, that it does not matter how limited the extent of the hatching operations may be, so long as the marketable fish produced are sufficient to give a profit on the cost of the operations. This at present we can neither prove nor disprove. The capture at marketable size of one in a thousand of the fry liberated, means 200 from each spawner in the hatchery every year. It may well be doubted that so high a proportion is possible. If there were no fishery by man the species would soon reach its limit of increase, and then on the average each pair of mature plaice would produce only two mature offspring to succeed them. This would mean a survival of two out of 200,000 eggs supposing each female spawned only once. But in the first place fish are marketable before they are mature, and therefore more than two marketable fish would survive, and in the second place the species being below its possible abundance excess of food is available, so that probably a greater proportion survive to marketable size. Then again, the eggs and fry are protected in the hatchery. But taking all these facts into consideration we may well doubt whether more than fifty out of the fry derived from each spawner in one season reach marketable size, and then we have to consider what proportion of these would be caught.

At present then it must be held that artificial propagation is in its experimental stage. There is good evidence that it produces local increase in the fish supply, the fish hatched in a particular place being carried or migrating to other definite areas in particular directions in consequence of currents, the habits of the fish, &c. It is possible therefore, if proper investigation be made, to trace out the history of the fry liberated from a hatchery, and to prove definitely what proportion of increase in the abundance of fish is produced by its means in particular localities. In future inquiries two points ought to receive attention with regard to the question whether the mere hatching of the eggs and protecting the fry for the few days before the absorption of the yolk is of very great benefit. The first point is the possibility of feeding and rearing the larvæ until they have gone through their transformation, and even until they are marketable. In this way a smaller percentage of loss in the larval and young stages than occurs in the natural conditions might be obtained, in other words longer and greater protection afforded. The second point is whether cheaper and larger results might not be produced by taking a very much greater number of spawners, and merely putting the fertilised eggs into the sea in vast quantities. Hitherto, notwithstanding great care and attention, no one has succeeded in feeding and keeping the fry or larvæ alive for more than a few weeks, but it seems possible that the difficulties will be overcome in the future by keeping the fry in large enclosures supplied with suitable food and pure water. At Plymouth plaice fry were found to take both minute organisms obtained from the sea, and artificial food in the form of minute particles of minced sea-worms. The exact cause of their ultimate death was not evident. As to the second point, the decrease in the supply appears to be largely due to the diminution in the number of mature fish in the sea. The hatchery may be regarded as a reserve of spawners, and there is no reason except that of cost why thousands or even millions of spawning fish should not be kept at suitable places on the coast. The mere collection of fertilised spawn would certainly be cheaper and less laborious than the hatching of the eggs in ingenious and complicated apparatus.

In connection with all measures for increasing the fish supply the importance of reliable statistics becomes evident. All who have had occasion to occupy themselves with these questions have felt the inadequacy of the statistics hitherto available. The Board of Trade furnishes tables which profess to give the quantities of particular kinds of fish landed at particular ports, and the total quantities landed on our coast. But the difficulty is that we are not enabled by these tables to compare the yield of given areas in different years, or the relation of the fish caught to the number, size, and character of the fishing boats. A larger total yield generally means an increased number of boats and a larger area exploited, and is accompanied by a diminished supply from grounds which have been long worked. It is obviously unsatisfactory to endeavour by complicated administrative machinery to increase the fish supply, without the power of ascertaining whether any result has been produced, or how much result. It appears that the only satisfactory method of investigating the fish supply is to record the catch landed from every boat, and the region where the catch was taken. It may be thought that this is impracticable, but a little consideration will show that it could be carried out without much difficulty. There is a collector of statistics at every fishing port at present, but he has no means of obtaining accurate and complete results. If every master of a boat or net were compelled by law to declare the quantity of fish he landed in the ordinary local measures, and his place of fishing, the local officer could easily keep a record of all the fish landed, and the number and character of the boats which landed it. To take an example: we could ascertain from such a record how many trawlers, steam and sail, fished on or near the Dogger Bank in a given year, and so ascertain the whole quantity of fish taken there, and the quantity per boat. In this way we should have a real and certain knowledge of the condition of all our principal fishing grounds. Hitherto Royal Commissions and Parliamentary Committees have been appointed from time to time to find such things out, and have necessarily failed to do so. Statistics of the kind here recommended have already been extensively collected by the Scottish Fishery Board, but what is required is that the system should be made complete so as to cover all boats and all fishing grounds. It may be supposed that fishermen would not give true information about the ground where they had been fishing, but every one who has experience of fishery affairs knows that a competent man can tell from the nature of the catch whether a statement made as to its place of capture is approximately correct or not. Any man, for instance, would be capable of distinguishing in his returns between fish from the coast of Iceland and fish from the neighbourhood of Heligoland, and this is the kind of distinction which is required.

PART II

HISTORY OF PARTICULAR FISHES

THE HERRING FAMILY

THE fishes of this family have no spines in any of their fins. They have a single short dorsal fin placed near the centre of the back, and usually a short ventral fin placed in the hinder part of the body near the tail. The pelvic or abdominal fins are below the dorsal or a little in front of it. There are never any barbels, the body is covered with scales, which are thin and spineless, and the head is without them ; the edge of the belly is usually more or less sharp, and covered with a row of scales which have keels ending in sharp points. The teeth are small and weak, the mouth large. The gill-openings are large. The lateral line is in nearly all cases absent. There is a well-developed air-bladder communicating with the hinder end of the stomach. The body is bluish or greenish on the back, very silvery and with iridescent colouring on the sides.

These fishes are never of very large size. They live in shoals, and swim always in mid-water or near the surface, feeding entirely on small free-swimming creatures, chiefly Crustacea. They do not usually seize single creatures with their jaws, but strain them from the water by means of the sieve-like apparatus formed by long projections on the gill-bars, known as gill-rakers.

The gill-rakers can be easily seen by raising or removing the gill-cover of either side in a herring or sprat. On the first or uppermost of the bars to which the gill-fringes are attached will be seen a row of stiff, pointed projections like the teeth of a comb or a rake. These are directed forwards towards the gill-cover and the throat, and the water that passes over the gills has to pass between them. Fishes of this family occur throughout the temperate and tropical regions. They belong to the neighbourhood of the coasts; none are found in mid-ocean, and none in the ocean abysses. Many species on the other hand approach towards fresh water at certain seasons, ascending estuaries and never going far from them; but no species is found only in fresh water, although there are colonies of certain species, such as shads, which have established themselves in lakes and remain there permanently and breed there. All these fishes occur in very large numbers, and partly from their method of feeding, partly from the persecution of numerous enemies to which they are exposed, they are very timid and restless and swim with very great rapidity. In consequence of these habits they are only caught with the drift net or the seine, or in bag nets and traps in narrow waters; the use of hooks for their capture is exceptional and unimportant.

There are six kinds in British water, all valuable as food, and several of them of great importance commercially. The following is a list of them with their chief distinctions:—

I. Species in which the mouth is at the end of the snout and the lower jaw somewhat longer than the upper. The sides of the upper jaw come forward when the mouth is open, and close the sides of the gape.

1. **The Herring.**—Dorsal fin commences midway between the end of the snout and the base of the tail; the pelvic fins a little behind the commencement of the dorsal. Scales of moderate size; edge of the belly not very sharp and the spines on it short and weak. No radiating lines on the gill-covers.
2. **The Sprat.**—Dorsal fin a little farther back than in the Herring; the pelvic fins very slightly in front of the commencement of the dorsal. Scales of moderate size; edge of the belly very sharp, and the spines on it strong. The body is rather deep and flattened from side to side. No radiating lines on the gill-cover.
3. **The Pilchard.**—Dorsal fin commencing nearer the snout than the base of the tail; pelvic fins under the middle of the dorsal. Scales large; the edge of the belly rounded, and the spines on it weak, not sharp. Radiating lines on the gill-cover spreading from above downwards.
4. **The Allis Shad.**—Like the Pilchard in other respects,

but the scales are smaller, the belly spines much stronger, the body deeper behind the head. The gill-rakers long, thin, and numerous.

5. **The Twait Shad.**—Distinguished from the Allis Shad best by the gill-rakers, which are sharper, thicker, and fewer; a row of dark spots along the side from the head to a point behind the dorsal fin.

II. Species in which the snout projects beyond the mouth, so that the latter is beneath the head; the sides of the gape unprotected when the mouth is open, and the gape itself reaching back far behind the eyes.

6. **The Anchovy.**

Of these six species the pilchard is the most truly marine in its habits, but is nevertheless, at some places, as at St. Ives, taken in very great numbers by the seine; it seldom enters estuaries. The anchovy also is not found in estuaries. Sprat and herring are found in brackish water, especially in the young state, while the shads regularly ascend rivers in order to spawn.

The eggs of these fishes have certain common peculiarities of structure, but the conditions in which they are placed to undergo their development are extraordinarily various. The spawn of the herring is deposited in the sea or near the mouths of rivers, and is heavy and adhesive, so that it sticks firmly to stones or fixed objects on the sea-bottom. The eggs of the sprat and pilchard on the contrary are of the buoyant kind, and float about separately in the sea like those of cod or flat-fish; the eggs of the anchovy are also buoyant and marine. The eggs of the shads are shed in fresh or nearly fresh water, and develop at the bottom of rivers, but they are not adhesive, remaining free and separate during development. The peculiarity of structure in which all the eggs resemble one another is that the yolk is compound, made up of a number of separate portions. In the herring these yolk masses are globules of various sizes and the eggs are not very transparent. In the other kinds the yolk masses are not globular, but angular from mutual pressure, and the eggs are quite transparent.

The hatched larva is very long and slender, and in all cases transparent, the vent is nearer to the tail than to the yolk-sac. The larva grows greatly in length, and remains very slender until its transformation takes place.

The Herring (*Clupea harengus*).

Principal Characters.—The pelvic fins behind the commencement of the dorsal, which commences midway between the tip of the snout and the base of the tail; nine rays in the pelvic fin. Scales of moderate size, thin, and deciduous; spines on the belly weak, and the edge of the belly rather blunt. No radiating lines on the gill-cover. Small easily detached teeth on the jaws, on the roof of the mouth, and the tongue. The hinder end of the upper jaw is beneath the middle of the eye. The colour a more distinct greenish-blue on the back than in the sprat. Seventeen inches is the greatest length recorded; the largest occur in the north—Iceland and Shetland; in Britain they seldom exceed $12\frac{1}{4}$ inches.

The points of difference between the herring and sprat in specimens of 2 inches long or less require some attention and care to distinguish, although they are perfectly certain and constant; in whitebait the young of the two kinds are usually mixed together. Besides the above points, the number of vertebræ in the sprat is never more than forty-eight, in the herring never less than fifty-four.

Habitat.—From the White Sea to the Bay of Biscay, absent from the Mediterranean. It occurs also on the American side of the North Atlantic, but not in the Pacific. It is abundant all round the British and Irish coasts, but chiefly in the North Sea and along the east coast of Scotland. In the English Channel the fishery is of less magnitude, and the quality of the fish inferior.

Breeding.—The proportional numbers of the sexes have been found in herrings to be very nearly equal, but there is a slight excess on the side of the males—namely, ninety-nine females to one hundred males. The sizes have not been compared with sufficient accuracy, but the testes were found to be on the average heavier than the ovaries, so that it is probable that there is a slight excess in size on the side of the males.

According to the careful calculations of Dr. Fulton, the herring is not individually a fish of very great fecundity. In sixteen specimens, $9\frac{1}{2}$ to $12\frac{1}{8}$ inches long, the total number of eggs varied from 21,000 to 47,000, the average being 31,000. All these specimens however were winter herring—herring that were ripe between January and March on the east of Scotland; most of them from the entrance of the Firth of Forth, a few from Wick.

The questions connected with the spawning periods and spawning places of herrings form a subject of which the investigation in this country is by no means exhausted. It is certain that herrings are found spawning in winter, and also in summer or autumn, and that the spawning periods differ considerably in different localities. It is not merely that in one neighbourhood the fish spawn in the beginning of the year, and in another at the end of summer, but that two spawnings have been definitely observed in the same neighbourhood. Considerable evidence has been obtained upon this complicated subject, and the conclusion to be drawn from this evidence is that the same herrings do not spawn twice a year, but that, on the contrary, the fish which spawn in winter are a different race from those which spawn in summer. These races differ in their habits and spawn in localities of different character. Winter-spawning herrings frequent brackish waters, and do not spawn far from the coast or the openings of rivers, while the summer spawners are herrings of the more open sea which, although they approach the coast in the spawning season, do not seem to enter estuaries, and whose spawning grounds extend to a considerable distance from the coast.

The herrings of the Firth of Forth are winter herrings. Their movements and spawning are regularly repeated every year both as to time and place. The spawn of herrings was first obtained from the natural beds and examined in the case of these herrings, in Professor Allman's investigation already mentioned in a previous part of this book. The fish first appeared, and the fishing in the upper parts of the Firth, below Queensferry, commenced about the last week of October, 1861. The herring were fished in the lower parts in January, 1862, and up to the end of January the fish taken were full. Spent herrings were taken on February 1st. After fruitlesss search in other parts of the Firth spawn was first obtained on March 1st near the Isle of May, and continued to be dredged there in abundance till March 13th. The spawn was sticking to stones, gravel, and shells in great abundance. The ground where the spawn was deposited was stated to be too rough and rocky for trawlers to work over.

When the present author was stationed at Granton in the years 1884–87 he had frequent opportunities of repeating Professor Allman's observations. He found evidence that the spawning commenced as early as January 18th. The ground, however, was not altogether unvisited by trawlers. At that time a number of steam trawlers worked from Granton, and in January, February, and March these used regularly to trawl over the herring-spawning ground for the purpose of netting the immense number of haddocks which congregated there to feed on the herring spawn. On one occasion a trawler got his trawl so full of haddocks that he could not hoist it on board, but towed it to Granton harbour with the fish in it. These haddocks were found to have their stomachs gorged with herring spawn.

Another regular winter-herring fishery which has been studied by naturalists is that of the Ballantrae Banks on the west coast of Scotland, off the village of that name in Ayrshire. Here the spawning takes place in February and March, and an examination of the beds and of the spawn, which was dredged up from the gravelly bottom in large quantities, was made in 1884 by Professor Ewart on behalf of the Scottish Fishery Board. Another naturalist, Mr. George Brook, studied the movements of the herring in the Firth of Clyde for several months, and considered that the famous Loch Fyne herring were fish which entered that loch after shedding their spawn on the Ballantrae Banks. It would seem extremely probable in this case that the Loch Fyne herring are hatched and reared within the limits of the Firth of Clyde, and belong to that region as permanently as perch or pike belong to their own river. At the same time it must be mentioned that spawning herring were found in Kilbrennan Sound and near Campbelltown in August and September, and whether these are also local fish, or a race belonging more to the open sea, there is not sufficient evidence to show. We have at present no reason to suppose that the same herring spawn twice a year.

The herring of Plymouth are another race of winter herring. The full-grown fish are captured from October or November onwards in Plymouth Sound, and their roes are in the full condition, gradually approaching ripeness. Spawning takes place only in Bigbury Bay, which is just outside Plymouth Sound to the eastward. But although it has been regularly observed that the ripe fish pass out to that locality in January, followed by the fishing boats, and that the spent fish and the newly hatched larvæ are taken there in numbers, yet in spite of continued and careful searching with the dredge we have never succeeded in obtaining the spawn from the bottom. Spawning continues until the beginning of March. Winter herring are known, and give occasion to fisheries of greater or less importance at various other places round our coast, but up to the present time no other spawning places than those above mentioned are accurately known.

The summer herring are more abundant and give rise to more important fisheries. As in the case of the winter herring, although large numbers are caught when they are not spawning, or about to spawn, the largest fisheries depend on full or ripe fish, and when the spent fish begin to form a large proportion of the catch the fishery is nearly over. The greatest of such herring fisheries are those of the North Sea, along the east coasts of Scotland and England, and the fish are taken at distances varying from two or three to fifty or sixty miles from the coast. Along the north-east coast of Scotland from Wick to Aberdeen the great herring fishery lasts from the middle of July to the end of August, and spawning takes place principally in the latter month. At Wick there is also a winter spawning in January. The spawning grounds in this district are not properly known; fishermen point out certain grounds as those where herring spawn is deposited, but the localities have not been determined from actual examination by experts. In all probability the trawlers do sometimes bring up herring spawn, and know particular grounds where they catch haddock in unusually large numbers, because those fish are attracted thither by herring spawn, but this kind of evidence has not been criticised with scientific accuracy. Dr. Fulton, in the Ninth Report of the Scottish Board, published charts showing the position of such alleged herring-spawning grounds on the evidence of Fishery Officers. But, on the other hand, these Officers have forwarded to headquarters pieces of hydroids from the sea bottom bearing small clumps of adhesive eggs, which they supposed to be herring spawn, and which are now known to be the spawn of the little sucker-fish called *Liparis*. Herring spawn when found is always in irregular masses or layers without any particular size and arrangement, while these clumps are rounded, and all of about the same size. The search for the actual deposits of herring spawn is by no means easy. In an expedition for the special purpose of this search in August, 1883, in which the author took part, and which was made in the Moray Firth on board the *Jackal* in the service of the Scottish Board, in spite of numerous dredgings no herring spawn was obtained.

I have been informed however by Mr. James Alward, of Grimsby, that it is well known to himself and to the line fishermen of that port that herrings spawn regularly every year in August and September on the rough ground of the west shoal of the Dogger Bank, and that it used to be the practice to look for herring spawn adhering to the grease placed at the end of the sounding lead, and to shoot the lines where the spawn was found, the fishermen knowing by experience that an abundant catch of haddock could be confidently expected on ground where herring spawn was lying.

From Aberdeen southward to Northumberland the principal spawning time is August and the early part of September, and further south it becomes later, off Yorkshire taking place chiefly in October, while at Lowestoft and Ramsgate it occurs in November. Although the actual spawning grounds are uncertain, nothing is easier than to obtain the spawn from the ripe fish on board a fishing boat at any of these places. It can be received on glass plates, and if placed in water with a little milt becomes fertilised, and can be hatched on shore provided a constant supply of clean sea-water is maintained.

The most complete investigations of the spawning of herrings in their natural condition, and of the natural history of the fish generally, are those made and published by a Commission of German naturalists at Kiel, in the Baltic. This was a Commission for the Scientific Investigation of the German Seas, instituted in 1870 by the Prussian Minister of Agriculture and

Industries, and its researches upon the herring were continued from 1874 to 1882. With regard to the spawning times and places, the investigations proved that the spring herring spawned in waters of little saltness and in shallow places in the Western Baltic from the beginning of April to the middle of June. In the river Schlei herring of this race actually spawn in water which is all but fresh, and the spawn is found attached to fresh-water plants. The autumn or sea-herring, on the other hand, were found to spawn in the salter, deeper water of the Great Belt and on the Mecklenburg coast from September to the middle of October. One spawning ground off the island of Langeland was at a depth of one to four fathoms, while the depth of the spawning ground of the spring herring in the Schlei was only 2½ to 3 feet.

One of the members of this Commission carried out a most laborious and profound examination of the minute peculiarities of herring from different localities, and satisfied himself that the different races could be distinguished by certain combinations of characters when a sufficient number were examined, although the differences were not sufficiently great to enable one to distinguish with certainty a single specimen by itself. He examined sixteen different local forms, and found that they were all distinguished by particular combinations of minute characters. Among these sixteen were the autumn herring of Peterhead, autumn herrings from the coast of Sweden, spring herrings from Bergen, the above-mentioned forms of the Baltic and others. But the sixteen different races formed three groups, whose differences were more pronounced—namely, a number of local races spawning in salt water, two races spawning in brackish water, and a third group, consisting principally of a Norwegian and an Iceland race. The view to which these results tend, whether they can be considered conclusive or not, is that a particular breed or race of herrings belongs to every particular spawning ground, and returns to it regularly every year in order to spawn there, and that on the British coasts these local breeds form two groups between which the differences are greater than those which separate the several breeds themselves. These two groups are the autumn herring and the spring herring.

These results have not yet been confirmed by British naturalists, nor has the method been applied to many of the British races. Mr. Duncan Matthews made an extensive examination of Scottish herrings, and detailed the results in the Fourth and Fifth Reports of the Scottish Board, and his conclusion was that the German naturalists' results could not be considered as applying to the forms examined in Scotland. But Mr. Matthews does not seem to have applied the German method in such a way as to make a thoroughly sufficient trial of it, and his opinion cannot be regarded as conclusive.

Putting aside this extremely technical method of examination, we have the certain fact that particular spawning grounds are visited once a year regularly at the same season, while other grounds are used at another time of the year. It seems only possible to conclude from this that a particular ground belongs to a particular breed of herrings which uses it from generation to generation, although it happens at times that particular grounds are deserted for a succession of years. Many cases are known where such grounds have been regularly used for a very great number of years. How then can we account for the fish always coming back to their own ground? This need not be so mysterious as it appears at first sight. Conditions of temperature and food very probably always drive the young fry from a certain ground in one direction, for instance up an estuary. There they remain together and meet with others a year older. The year-old forms when ready to spawn for the first time very probably join the shoals of mature fish when they revisit the same neighbourhood, and so without any marvellous instinct accompany them to the spawning ground which they already know from habit and memory. The case is similar to that of migratory birds; it is not entirely an incomprehensible intuitive instinct, but a more comprehensible instinct of joining the older flocks; the simple habit of herding in flocks or shoals is probably the explanation of the whole matter. In order to obtain more certain knowledge about the migration of herrings a great deal of systematic and organised investigation will be necessary. We may safely consider that the old theory which taught that the home of the fish was in the northern seas, and that they annually migrated southwards in one great body at the same time, and that this was the reason why the fishing season was later at southern parts of the east coast than at the northern, is exploded.

For if this theory were true, it is clear that the herrings could not be in the ripe and spawning condition at every stage of their journey, and they actually are full and ripe at each place where the summer fishing is carried on—at Wick in July, at Lowestoft in November. The fish that spawn at Lowestoft in November cannot be the same fish which spawned off Dunbar in September. We must conclude that the fish which escape the nets of the fishermen after spawning in any district depart and go back by the way they came. But still they must even on this more correct view come and go, and we have to consider whence they come and whither they go. We have good reason to believe that adult herrings do not remain in the North Sea in very large numbers except in the spawning season, at least not in the narrower southern parts of the North Sea. We are compelled therefore to conclude that they retire to the deeper, more northern waters of the Norwegian Sea. The migration in fact appears to be towards the coasts and away from the coasts. Different shoals seek different spawning beds at different times of the year. But to what distance their migrations extend, and whether they remain in shoals after they leave the spawning grounds, or disperse, are questions which we cannot answer.

The appearance of the egg of the herring under the microscope is shown in Fig. 84. The yolk is composed of a large number of small spherules, as in the case of other adhesive eggs, but there are no separate oil-globules. The space between the egg-membrane and its contents is greater than it usually is in buoyant eggs. The egg when shed is globular, but its surface becomes flattened where it is attached to other eggs or to solid objects. The size of the egg varies somewhat in different localities; at Ballantrae it was found to be 1·5 mm. ($\frac{6}{100}$ inch) across after fertilisation. In the developing egg the embryo is long compared to the size of the yolk, so that before the tail has grown out into a free projection the head and tail almost meet round the yolk.

The time occupied in development before hatching varies with the warmth or coldness of the water. Eggs obtained in August off the Farn Islands and kept at 52° to 58° hatched out on the eighth and ninth days. Eggs obtained at Plymouth on January 26th hatched in from twelve to fourteen days at the temperature of about 48°. In experiments made at Kiel it was found that eggs kept in water at 32° took forty-seven days to hatch, and many of the larvæ were deformed; at 33° and 34° however they took only a little less time, and were uninjured.

The newly hatched larva (Fig. 85) is 5·3 mm. (over $\frac{1}{5}$ inch) in length, and is more developed than the young of fishes which are hatched from buoyant eggs. The eyes are black, and the mouth is open, but the latter is on the lower surface of the head and

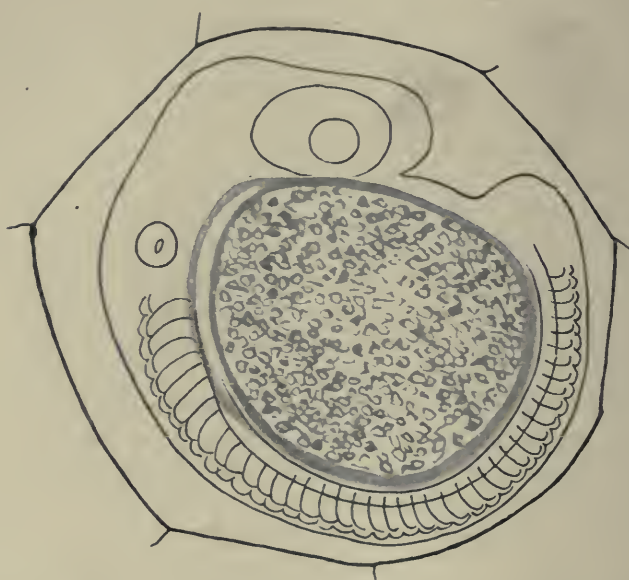


FIG. 84.—Egg of the Herring, the embryo about half developed, alive, and magnified.

the jaws are not developed. The gill-slits are also open, but there is no gill-cover. The intestine extends back a long way behind the yolk-sac, the vent being near the end of the tail. The fin-membrane extends along the back and round the end of the tail, and also between the vent and the yolk-sac. There is very little pigment on the body, only a few black specks, none on the fin-membrane. After the yolk-sac is absorbed the little fish continues for some time to grow in length without becoming much thicker. The jaws develop, and by the time the larva is

$\frac{5}{12}$ inch long fine fin-rays appear in the tail and in the middle of the back, indicating the dorsal fin. The ventral and pelvic fins appear later. After the larval fin-membrane has disappeared, when the little fish is $1\frac{1}{2}$ to $1\frac{3}{4}$ inches long, although the bones of the head are well developed the body is still slender and very delicate and transparent, having neither scales nor silvery layer in the skin.

The transformation of the larval herring, or the most important changes, take place in the case of the spring herring of the Baltic, and probably in other spring races, between the ages of two months and three and a half months, and between the lengths of 1 inch and $1\frac{4}{5}$ inches. The change consists in the development of the scales and silvery layer in the skin, and the growth of the body in depth and thickness. During this change the dorsal fin passes forwards nearer to the head. When the fins

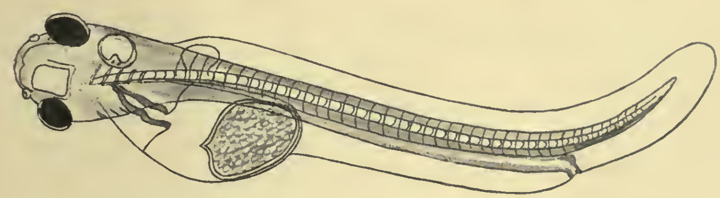


FIG. 85.—Larva of the Herring newly hatched, alive and magnified.

first appear the dorsal is considerably behind the pelvic, and nearer to the ventral than in the adult fish, but after the change the commencement of the dorsal is in front of the pelvic or hinder pair of side fins.

The most accurate and complete observations on the history and growth of young herring are those made by the German naturalist Meyer in the Baltic in the neighbourhood of Kiel. An account of these will first be given here, and then some observations on young herring in our own country will be described and compared with them.

The spawning of the spring herring at the mouth of the river Schlei begins at the end of March, and takes place principally in April and May. At the end of May, 1874, numerous young (larvæ) derived from this spawning were netted in the Schlei, and were found to be 1 inch to $1\frac{1}{5}$ inches long, on June 10th others were captured which were $1\frac{3}{10}$ inches long, and on June 23rd others $1\frac{7}{10}$ inches. The specimens taken at the end of May and June 10th must have been hatched about the middle of April, and so would be about six weeks old.

It was found that the transformation from the scaleless, transparent, larval condition, to the condition of perfectly formed small herring took place in the Schlei in July, and by the end of that month the majority had got beyond the intermediate or transition period and were fully developed. They were then $1\frac{4}{5}$ to $2\frac{1}{5}$ inches long. The process of change, and the time required for it, were observed not only by the capture of specimens from time to time, but also in specimens confined in a floating box. These specimens were 1 inch or a little more on June 11th when the experiment commenced, and on August 1st, or after about six weeks, were $1\frac{4}{5}$ inches long, and were silvery and covered with scales.

At the end of August and beginning of September the little herrings left the mouth of the river and were found in the neighbouring bays, but mixed with other larger herrings evidently derived from a different and earlier spawning. Meyer therefore measured the growth by taking the lengths of the smallest fish in each catch; the results were these:—

		Inches.
1876.—	14th November	3·3
	End of November	3·5
	End of December	3·9
1877.—	End of January	4·3
	End of February	4·5
	End of March	4·9
	End of April	5·4

As the smallest fish only were measured, we may conclude from this that these herrings were 5 to 6 inches long when one year old.

In 1878 the same naturalist took a great deal of trouble in order to try to rear in confinement herring larvæ hatched from artificially fertilised eggs. The larvæ were placed in a large tub about three feet wide and two feet deep, with a wooden cover. A hole was made in the side about midway between top and bottom and plugged with a sponge. Through this the water gradually drained away until it was level with the hole. Clean water from the Bay of Kiel was poured in once a day. After the eleventh day of age the larval herring began to die off, and those which lived did not grow very fast. Food was found in the intestines of some specimens, and consisted of the minute larvæ of common bivalve and univalve molluscs. On the forty-seventh day after the fertilisation of the eggs the survivors measured only $\frac{12}{25}$ inch, while the free larvæ in the Schlei measured $\frac{17}{25}$ inch. The water up to this time had been poured in through a cloth, to keep out animals which might feed on the little herrings, but after this it was poured in directly and then the young herring obtained more food, eating the small crustacea in the water, and at the end of five months were as large as the young fish of the same age in the Schlei. The lengths observed were as follows:—

Age from fertilisation of the eggs.	Length of captive specimen. Inches.	Length of young herring in the R. Schlei. Inches.
1 month	—	$\frac{17}{25}$—$\frac{18}{25}$
2 ,,	$\frac{17}{25}$—$\frac{19}{25}$	$1\frac{9}{25}$—$1\frac{11}{25}$
3 ,,	$1\frac{1}{5}$—$1\frac{2}{5}$	$1\frac{4}{5}$—2
4 ,,	2—$2\frac{1}{5}$	$2\frac{1}{5}$—$2\frac{2}{5}$
5 ,,	$2\frac{3}{5}$—$2\frac{4}{5}$	$2\frac{3}{5}$—$2\frac{4}{5}$

With regard to the growth in the second year, Meyer first of all considers the size or length at which herrings spawn for the first time. According to his own experience the smallest ripe herrings were 7·9 inches long, and since at a year old they were not so large as this, but only $5\frac{1}{2}$ to $6\frac{1}{2}$ inches long, he considers that they begin to spawn at two years of age. This, although a probable conclusion, can only be regarded as a preliminary conjecture, and a thorough investigation of the question, based on a large number of observations extended over a considerable time at one place, has yet to be made.

A few observations on young stages of herring in our own country are worth mention, as giving some, although not very complete evidence on the history and growth of the fish. It is well known that the whitebait caught for the London market in the lower reaches of the Thames has been fully proved to be a mixture of young herrings and young sprats in varying proportions. In the Fourth Report of the Scottish Board is contained a paper giving the results of an examination of samples of these whitebait. These results are shown in the following synopsis:—

Month.	Number examined.	Percentage of Herrings.	Condition of the Herrings.
February.	1,400	7	Some under 2 inches.
March....	1,200	5	Some nearly 4 inches.
April......	800	14	12 per cent. of the herrings under 1½ inches without scales.
May	600	30	40 per cent. of the herrings 2 inches long and completely scaled; 60 per cent. 1½ to 1¾ inches and only partly scaled.
June	800	87	60 per cent. of the herrings fully scaled 2 to 2¼ inches long; 40 per cent. 1 to 1½ inches scaleless or nearly so.
July	600	75	1½ to 2½ inches.
August ...	500	52	2 to 3 inches.

It is evident from this that larval herring not yet transformed to the fully developed condition began to appear in April, were most numerous in May, and were still a large proportion of the whole in June, while the older scaled forms became more numerous in June and July, and in August no larval forms remained, all the young herrings being over 2 inches in length. All this points strongly to the occurrence of a spring spawning at the mouth of the Thames in March and April, but unfortunately such spawning has not been sufficiently investigated. But in Yarrell's *British Fishes*, first edition, vol. ii., p. 117, there is an account of certain herring which that author found in the Thames. They were captured by the sprat fishermen, and were heavy with roe at the end of January, spawning in February. They were small, only 7½ inches long, and Yarrell considered them to be a distinct species. The fishermen of Leigh, on the north shore of the Thames estuary, maintain that the herrings they catch in winter, which they call "yorlings," a corruption apparently of yearlings, are not the same as sea herrings, but a different variety. These are apparently the same which Yarrell described, and probably are a race of spring, brackish-water herrings belonging to the mouth of the Thames. It is probably from these herrings, whose spawning may continue in March and April, that the young which form so large a proportion of Thames whitebait are derived. The actual place, however, where the spawn is deposited has not been ascertained.

The history of the larvæ hatched on the spawning beds of the Isle of May in the Firth of Forth, has not been completely traced out. The newly hatched larvæ were obtained at St. Andrews in March, and specimens a little older were obtained in abundance in April. It is probable that the majority of these young herring pass the first year of life in the upper reaches of the Forth, but they have not been examined. In December, however, it was found[1] that considerable numbers of herring 3¼ to 5¼ inches long were taken in the sprat fishing of the Firth of Forth. These must be considered to be derived from the Isle of May spawning in the previous spring.

At Plymouth, again, the history of the herring hatched in January, February, and March has not been completely traced. In 1895 the larvæ occurred in the tow-nets in January. In May, 1889, a large number of small herring were taken in a ground seine in the Cattewater, the estuary of the Plym ; these measured 4·3 to 5·5 inches in length, and were judged to be year-old fish, hatched the previous spring in February and March. In October herrings of 5 to 8½ inches are abundant in the Hamoaze, and these are probably the mixed broods of two years.

The history of the summer or sea herring is still less satisfactorily known than that of the winter or spring herring. According to the observations of the naturalists at Kiel, the young of the autumn herring are taken mixed with those of the spring herring in July and August, in the bays of the Western Baltic. These fish are 2·5 to 3·7 inches long at that time when they are 8 to 10 months old. The German naturalist Heincke found that the larva of the autumn herring was different in shape from that of the spring herring, and that its transformation took place later, when it was of a larger size, so that it was never less than 2 inches long when the perfect form was reached. No observations of any importance have been made on the young of the summer and autumn herring in this country. It may be mentioned, however, that among these herring in the fishing season a considerable proportion of mature ripe fish are only 8 to 8½ inches long. These in Scotland are usually called matties, a term which is sometimes supposed to be applied to herrings that are not full of roe, but immature. These are really the smallest mature, and may be taken to show the size at which maturity is reached in the autumn herring, the age being as before mentioned two years.

[1] *Sprat Fishing on the East Coast of Scotland in the Winter of* 1883–84. Second Report of the Fishery Board for Scotland.

The Sprat (*Clupea sprattus*).

Distinguishing Characters.—The dorsal fin commences a little behind the middle point between the snout and the base of the tail fin, and the pelvic fins are very slightly in front of the commencement of the dorsal. There are seven rays only in the pelvic fin. The scales are a little larger than in herring of the same size. No teeth on jaws, tongue, or roof of mouth. The spines on the belly strong and sharp, and the edge of the belly narrow, so that it is like a saw. The body deeper than in the herring. The hinder end of the upper jaw not reaching back so far as the middle of the eye. No radiating lines on the gill-cover, the lower edge of the opercular bone not slanting upwards and backwards so much as in the herring, and straight. The colour of the back rather dull and slaty. Does not exceed 6½ inches in length, usual size 4 to 5 inches.

Habitat.—From the north coast of Europe to the Mediterranean. Found all round the British and Irish coasts. There are large fisheries of sprats in the neighbourhood of the Thames, on the Kent and Essex coasts, and along the south coast of England, as in the Solent and at Torquay. They are also taken in the Forth and Tay, and in the Moray Firth. In narrow waters they are caught in stow-nets, as in the Thames, the Wash, and the Forth. At Dover they are caught with small-meshed drift-nets, and at Torquay in seines.

Breeding.—The proportions between the sexes have not been carefully studied, and the investigation of the number of ova by Dr. Fulton was imperfect, as the roes were not very ripe or very fresh. He calculated in one specimen the total number of eggs at 5,400.

Ripe sprats are not often seen in large numbers, not usually being taken in this condition in the regular fisheries. The reason of this appears to be that the fish go some distance from shore in order to spawn, and there is no regular pursuit of them in the ripe condition. The case resembles that of the pilchard. The spawning season must therefore be determined rather from observation of the presence of the buoyant eggs in the sea than of the proportion of ripe fish taken. It is probable that if small-meshed nets were used, and a careful trial made, numbers of spawning or ripe sprats could be captured. But it happens that the longshore fishermen who capture sprats do not fish in the open sea, and the deep-sea fishermen do not use nets which are capable of catching sprats.

When the reproduction of the sprat was first considered, it was naturally supposed that its mode of spawning would probably prove to be closely similar to that of the herring. In 1884 Mr. Duncan Matthews wrote that he obtained sprats with full roes and milt from the coast of Scotland only in May and June, and that many were so ripe that the roe could be readily expressed by the hand, when it presented much the same appearance as the spawn of the herring under similar circumstances. He gave a figure of the spawn pressed out in the form of a string of eggs lying on a glass plate. In the same year I published a description of a pelagic or buoyant fish-egg, the parent of which was unknown. This egg was obtained by me in the Firth of Forth in May and June, and it has since been proved that it is the egg of the sprat. The same egg was described about the same time by Victor Hensen from the Baltic, and that observer first suggested that it belonged to the sprat, an identification which he afterwards proved to be correct by pressing the eggs from a perfectly ripe sprat. I have myself been able to confirm the identification by examining eggs pressed from ripe sprats at Plymouth. On board a trawler on February 12th, when the net was hauled after being towed from Looe in Cornwall to a point about five miles from Plymouth Breakwater, I found two sprats amongst the fish caught. One of these was a perfectly ripe female, and I pressed out a number of eggs, which floated in the sea-water, and which were taken ashore and carefully examined with the microscope. They were not fertilised, but they showed the peculiarities so well known in the egg taken by the tow-net from the sea.

The spawning period of the sprat is prolonged; the eggs are found at Plymouth from the end of January until the end of April or even later; at St. Andrews they have been taken from April to July, and on the west of Ireland they were observed in March, April, May, and June.

The egg of the sprat (Fig. 86) is from ·94 to 1·2 mm. in diameter (a little more or less than $\frac{1}{25}$ inch). It is to be recognised by the division of the yolk into separate portions, which appear under the microscope as though separated by fine lines. The whole egg is extremely transparent. There is no oil globule, and the space within the egg-membrane is small.

The egg develops and hatches in a very short time, namely,

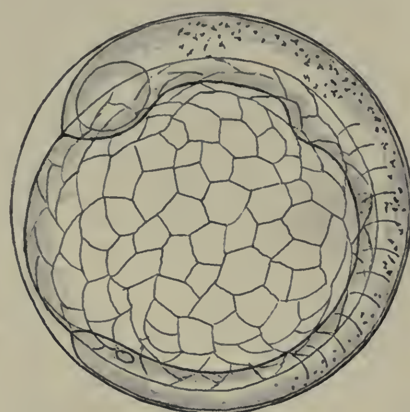


FIG. 86.—Egg of the Sprat, alive, magnified.

three or four days. The length of the larva or young sprat when first hatched is 3·0 to 3·7 mm. ($\frac{12}{100}$ inch to $\frac{15}{100}$ inch). As may be seen in Fig. 87, it is by no means so far developed as the newly

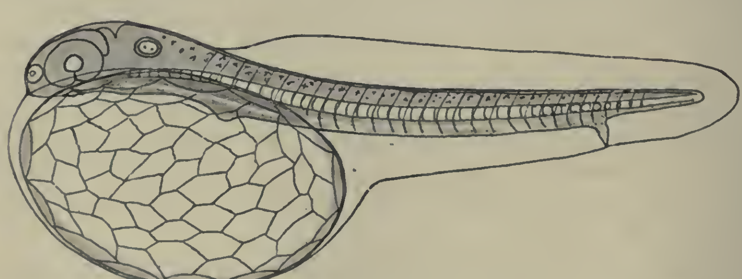


FIG. 87.—Newly-hatched larva of the Sprat, alive, magnified.

hatched herring, the mouth not being open, and the eyes being unpigmented. It is very transparent, and there are only a few minute black specks on the body. The position of the vent near the end of the tail is the same as in the other members of the family.

The transformation of the sprat larva into the perfect, fully-developed sprat has not been carefully studied, but it is known to resemble closely that of other fish of the herring family. But concerning the growth and general history of the young we have a considerable amount of evidence. The interesting observations of Ewart and Matthews on Thames whitebait, already used in connection with the herring, contain equally valuable information concerning the young of the sprat. The condition and proportional numbers of these are shown in the following table:—

Month.	Number of Whitebait.	Percentage of Sprats.	Length of Sprats.
February .	1,400	93	2 to 3 inches.
March ...	1,200	95	2 to 2½ inches.
April	800	86	2 inches average.
May	600	70	2½ inches.
June	800	13	1 to 2¼ inches, the smaller without scales.
July	600	25	8 per cent. of the Sprats under 1¼ inch without scales.
August ...	500	48	1 to 1½ inch.

The number of small scaleless sprats gradually increased during the last month, until 90 per cent. of the samples consisted of these. This shows that the new brood of the year began to appear in June, and increased to the end of August. The transformation was completed when the fish were 1¼ inch long. We have no direct observations of the period of spawning at the mouth of the Thames, but may infer that it extended from March to June, the fish being first caught when about two months old. We see therefore that the little sprats 2 to 3 inches long taken at the beginning of the season in February, March, April, and May, were just about a year old.

The smallest ripe or nearly ripe sprats seen by Matthews in the Firth of Forth were 4 to 4½ inches long, and here again it is probable that this length and the commencement of sexual maturity is not reached before two years of age.

Young sprats fully developed, known locally as "britt," are exceedingly abundant at Plymouth and other places on the south coast of England, and are greedily devoured by mackerel, other fishes, and sea-birds. They are commonly seen in summer time. I have examined specimens in November 2·2 to 2·6 inches long. In December I saw a large number killed in Millbay Docks by submarine blasting; these were 2·2 to 2·4 inches in length. In April specimens obtained outside the Breakwater were 3·3 to 3·8 inches long. The latter were doubtless a year old or a little over, the others a month or two younger. The summer britt appears to include the sprat fry of two years. I have not examined it carefully myself, but, according to Day, the little sprats in August at Dawlish were $\frac{3}{4}$ inch to $2\frac{1}{2}$ inches long. Those of the latter size could scarcely have been hatched in the preceding spawning season, even in January, while the smallest are evidently the young of the year, hatched in the preceding spawning period.

Migrations.—It is evident from the above account that the young sprats after hatching approach the shore and enter bays, the mouths of rivers, and even docks. The britt less than one year old are abundant and conspicuous in inshore waters all summer and autumn, and remain there during the following winter and summer. But the older sprats which are sexually mature are only caught in autumn and winter on the south coast. The obvious meaning of this is that they migrate seawards during the spawning period, and regularly return towards brackish waters afterwards. Thus from the Thames to Torquay the principal sprat fishery is from October to the end of January. The sprat fishing for full-grown sprats in the Firth of Forth takes place in December, January, and February. It would appear however that the mature sprats do not return towards the shore immediately after the spawning period, since at Plymouth that period seems to terminate in May, and there is no sprat fishing until the following September at earliest. There is room for further inquiry as to the position of adult sprats in summer after spawning, and their food at that time and during the early part of winter when they are captured in inshore waters.

The Pilchard or Sardine. (*Clupea pilchardus.*)

Distinguishing Characters.—Dorsal fin nearer to the snout than to the root of the tail; pelvic fin behind the commencement of the dorsal; last two rays of the ventral fin slightly prolonged. Teeth in the jaws very minute or absent, none on the tongue or palate. Radiating lines on the opercular bone, and beneath the eye. Upper jaw reaching back to the front third of the eye. Scales larger than in any other British species of the family, only thirty in the whole length of the body, easily detached. Spines on the edge of the belly weak, and the edge itself rounded; the whole form of the body is rounder than in herring or sprat, and not so deep. Colour on the back olive green, rather deep, sides silvery. Does not often exceed 11 inches in length, and 8 or 9 inches is the usual size. Mr. Dunn has seen a specimen 14 inches long, but this a rarity.

There is no difficulty in distinguishing the fully-developed pilchard at any size; it more resembles the shads than the sprat or herring, but is easily distinguished from the former by the more slender body, larger scales, and weaker ventral spines. The question whether pilchards and sardines are the same or not is frequently raised, and the correct reply to it is the following. The sardine of commerce is prepared on the west coast of France from Brest southward to La Rochelle, and therefore the fish is taken in a part of the sea which is near to, and not separated from, that where the Cornish pilchard fishery is carried on. The pilchard extends throughout both these parts of the sea, and the sardine is not a different fish. Pilchard is the Cornish name for it, sardine the French. But the fish which are preserved in oil and tinned are small, young fish, from about 5 inches to 6½ or 7 inches in length, and these are not regularly caught by the Cornishmen. The difference in the product is due to the difference in the mesh of the nets used. On the other hand full-grown pilchards 8 to 10 or 11 inches long occur on the French grounds, and are fished there in winter; they are distinguished as *sardines de dérive* which means drift sardines, sardines caught by drifting with the nets without bait, while the small fish of the summer fishery are called *sardines de rogue*, because salted cod's roe, called *rogue*, is scattered in the water as a bait to attract the fish before the nets are shot. Nets of various meshes are used in this fishery, and the fishermen use the mesh which is the right size for the fish present at the time. Seines however have come into use in the summer fishery in recent years. There is no reason to doubt that the small sardines could be caught in Cornish waters: in fact they have frequently been taken in the seines there, but were not wanted because not suited to the Cornish trade.

The sardine occurs also in the Mediterranean, and there, at Marseilles, for instance, it is a smaller fish when adult and mature, not exceeding 7¼ inches. But the sardine industry, the business of tinning sardines in oil, is not carried on apparently on the coasts of the Mediterranean, or if so has by no means such an importance as on the west coast of France.

Habitat.—As already mentioned the pilchard extends throughout the Mediterranean, but is a smaller race, just as plaice are smaller in the Baltic than in the North Sea. The oceanic sardine or pilchard extends from the southern shores of England and Ireland to Madeira. There is no great fishery for these fish on the south and south-west coasts of Ireland, although large numbers are sometimes taken near Cork, and the fish are abundant on these coasts. On the other coasts of Ireland or Britain the fish are only ocasionally taken in small numbers. The regular productive fishery does not extend eastward of the Bill of Portland, nor north of St. George's Channel. The distance to which the fish wander from the coast it is not at present possible to estimate with much accuracy. They are said to be seen at times fifty miles from the Scilly Islands.

Breeding.—According to Day, the number of eggs is about 60,000.

The relations between the breeding of the fish and its capture are in the pilchard exactly the reverse of those which exist in the case of the herring. Among the pilchards caught for the market it is a rare occurrence to find any which are in a gravid condition. When pilchards caught in the ordinary course of the fishery are opened, their generative organs are usually found to be small and undeveloped; the process of spawning has either been recently completed, or the ovaries and testes have scarcely begun to enlarge in preparation for the next period of reproduction. In fact ripe pilchards do not form the object of a regular fishery. In my own experience I have seldom known ripe pilchards to be caught in a pilchard net. They are usually taken accidentally by nets intended for other fish; most of those that I have seen were captured in mackerel nets. The explanation of this lies of course in the habits of the fish. Ripe pilchards are usually only met with at a considerable distance from land, twenty to forty miles out to sea. Pilchard nets, whether drift-nets or seines, are usually shot near the shore, the drift-net boats seldom go much further than ten miles out. The ripe pilchards are taken in small numbers in mackerel nets in summer and early autumn. Possibly if pilchard nets were habitually used at the proper places and time of year ripe pilchards would be taken in large numbers, but the meshes of mackerel nets are much too large to catch pilchards in the ordinary way, the few that are retained by the meshes are caught not behind the gills, as fish usually are in a dift-net, but round the abdomen, which is swollen by the enlarged ovaries. As far as my own experience goes only the females are caught in this way, and I was for a long time unable to obtain a ripe male pilchard. Probably the ripe males are not distended so much as the females, and therefore pass through the meshes of the mackerel nets without being retained. Probably, too, only the largest females are caught. The number taken in a fleet of mackerel nets at one time varies from one or two to fifty or more, but scarcely ever exceeds a hundred. The time at which they are taken is not limited to a few weeks, but extends from the beginning of June to the end of October; they are commonest in July and August.

The eggs of the pilchard when shed are not heavy and adhesive like those of the herring, but float about separately in the sea, like those of the sprat and anchovy. As early as 1865 Couch stated in his work on British fishes that he had reason to suppose that the spawn of the pilchard was shed at the surface, and floated in a quantity of tenacious mucus, but he gave no satisfactory evidence on the subject. Mr. Dunn informed the Commissioners for Sea Fisheries, in 1879, that he had pressed ripe spawn from a female pilchard in May, 1871, and that the eggs floated separately in a bucket of sea-water. But no microscopic examination of the egg was made till many years afterwards. In 1888 Raffaele, an Italian zoologist, described among the eggs he found floating in the sea one which evidently belonged to some fish of the herring family, and which he thought probably belonged to the sardine. Not long after I began to work at Plymouth I obtained from the open sea a buoyant egg similar to that described by Raffaele, and found that the ripe unfertilised eggs squeezed from female pilchards had the peculiarities in the condition of the yolk seen in this egg, and in no other egg hitherto examined from our seas.

It was not till 1893 that I succeeded in obtaining artificially fertilised eggs of the pilchard. These were taken on September 5th, ten miles south of the Eddystone, by the crew of a boat to whom I had given bottles for carrying the eggs and instructions for handling them. In this case the boat was using pilchard nets and fishing for pilchards, but was working farther from the coast than usual. In the catch of 2,200 fish a few ripe specimens were found, and the eggs were brought to me next morning in good condition and in process of development. The eggs agreed perfectly with those previously obtained from the sea.

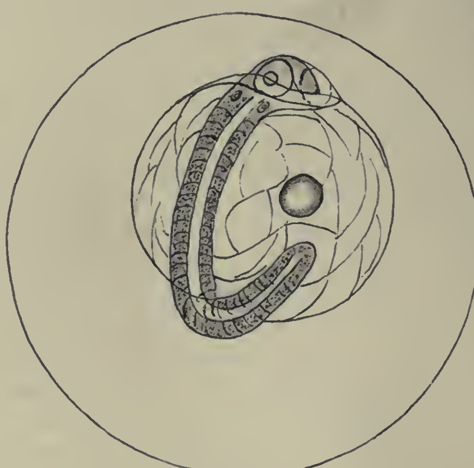


Fig. 88.—Egg of the Pilchard, alive, and magnified.

The appearance when magnified of the living pilchard egg in course of development is shown in Fig. 88. The egg is completely distinguished from the numerous other kinds which float in the sea by three unmistakable peculiarities. These are (1) the unusually large space between the egg-membrane and the enclosed egg, (2) the complete division of the yolk into a number of irregularly-shaped segments, (3) the presence of a single large oil-globule in the yolk. Neither of these characters alone is peculiar to the pilchard egg, but no other egg is known in British waters which possesses the three together.

Pilchard eggs are taken in small numbers when the tow-net is worked even a short distance from land in summer, but become more numerous farther out to sea. If the eggs are kept a few days in clean sea-water they hatch, and the larval fish that issues from them has the structure shown in Fig. 89. The artificially fertilised eggs mentioned above hatched in three days at a

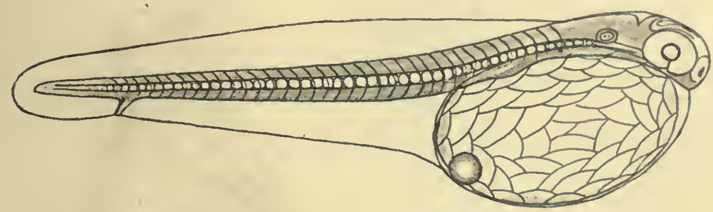


Fig. 89.—Newly-hatched larva of the Pilchard, alive, and magnified.

temperature of 62°. The larva is 3·8 mm. long (slightly over $\frac{3}{20}$ inch). The yolk is still large, the oil-globule at the hinder end of it, the mouth is not open, and there is no pigment except a few black specks along the back of the slender body. The mouth appeared on the third day after hatching, and on the fourth day the jaws were developed, the eyes were black, and the yolk almost all gone. On the fifth day I put some of the minute creatures gathered from the sea by the tow-net into the tank containing the larvæ, and also some minute particles of minced sea worms, and they began to feed. When five days old the larvæ were over $\frac{1}{5}$ inch long, and the yolk was all gone. When feeding the larvæ were seen to peck or strike at the particles which they swallowed, so that feeding is a deliberate and

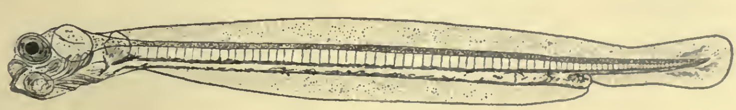


Fig. 90.—Larva of the Pilchard, nine days old, alive, magnified.

active, not a passive, involuntary process. Fig. 90 shows the appearance of one of the larvæ when nine days old.

The transformation stages of the pilchard have been traced by me in specimens captured at sea near Plymouth. The specimens were taken at the surface at night, in a large tow-net made

FIG. 91.

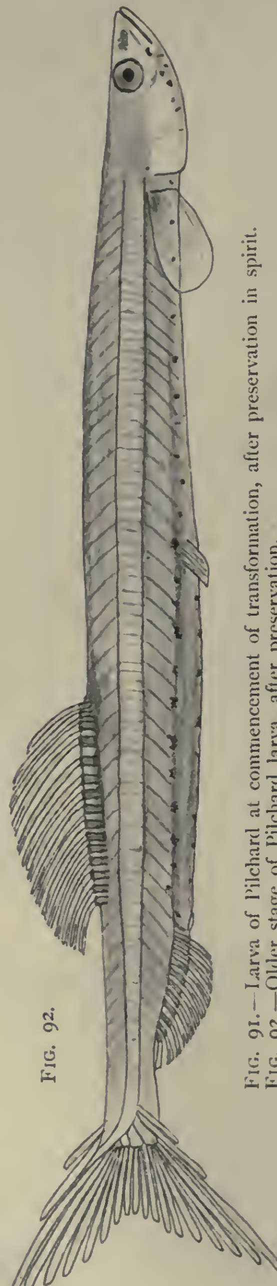


FIG. 92.

FIG. 91.—Larva of Pilchard at commencement of transformation, after preservation in spirit.
FIG. 92.—Older stage of Pilchard larva, after preservation.

of mosquito netting. They very closely resemble the similar stages of the herring or sprat, and the starting-point of the reasoning which leads to the conclusion that they are pilchards is the time of year at which they were taken. There are no herrings spawning in the neighbourhood of Plymouth in June or July, and sprat eggs are not usually seen there later than the beginning of May; pilchard eggs on the other hand are abundant from the beginning of June to late autumn. The youngest stage of the specimens in question, moreover, was smaller than the herring at an earlier stage of development.

The youngest of the specimens was 8·5 mm. long ($\frac{34}{100}$ inch). It was but slightly advanced beyond the condition of the oldest larva reared in confinement. The chief differences were that the fin membrane had disappeared along the belly in front of the vent, and was much narrower behind the vent and along the back; the tail was more distinct and more developed, and the dorsal fin had begun to appear on the back. In an older stage (Fig. 91), 11·5 mm. in length ($\frac{46}{100}$ inch), the dorsal fin was larger, and the tail more developed, but traces of the original fin membrane remained, and the hinder pair of side fins had not appeared. The largest specimens (Fig. 92) were 24 mm. long, or very nearly one inch, and in these the body was thicker, and the fin-rays much better developed; the original fin membrane was entirely gone, the tail was forked and like that of the adult, and the hinder pair of side fins were present. But the dorsal fin was still behind the hinder side fins; there were no scales or silvery coat, and the body was very long in proportion to its thickness.

At Marseilles and Nice, on the shores of the Mediterranean, very fine nets are used for the capture of swarms of minute fish fry, very much as in the whitebait fishing of England. In the Gulf of Marseilles, Professor Marion has traced the growth and development of the pilchard in the produce of such fishing throughout the first year of its life. The young sardines before the development of the scales and silvery covering are called by the fishermen *poutino nudo*, or naked fry; these are from $\frac{1}{5}$ inch to 1$\frac{3}{5}$ inch. At a larger size, 1$\frac{3}{5}$ to 2 inches, when they have acquired the silvery livery, they are called *poutino vestido*, or clothed fry. When still larger they are called *palailla* and *sardinettes*.

It has been abundantly established that the small pilchards taken on the west coast of France for the sardine industry are a year old, and are sexually immature. That they are not capable of spawning is certain, no development of the roe or milt having ever been seen in pilchards of this size. With regard to the age we have merely to assume that the fish spawns in the neighbourhood of the French coast in summer and autumn as it does on the English coast, or rather it may be said that we know that in the area of sea about the entrance of the English Channel the pilchard spawns from June to October. Therefore it is certain that the small fish which appear from May onwards are the produce of the preceding year; we have no reason to suppose that they are more than one year old. These fish are from five to seven inches long, and there is no regular succession of sizes as the season advances. The latter fact is not surprising when we consider the long spawning period, and the rapid movements of the shoals. Early in the season, in May, for instance, the fish caught may be those which were hatched in the early part of the preceding season, while in the next month shoals may appear which were hatched in September or October, and are therefore very much smaller. At the same time it has been observed that the sardines of the latter end of the season are larger on the average than at the beginning. The facts here mentioned concerning French waters are obtained from the observations of the late Professor Pouchet, who studied the natural history of the sardine at Concarneau on the coast of Brittany. In the years 1887 to 1890 there was a serious crisis in the sardine industry of France, the fish having failed to appear on the coast in their usual abundance. The Government were anxious, as usual in such a case, to obtain as much accurate information as possible from scientific men, concerning the life, reproduction, and history of the fish, and Professor Pouchet on the west coast and Professor Marion at Marseilles endeavoured to obtain the information, which as usual was not available and not energetically sought until a special demand arose. The Cornish industry has recently suffered from a depression caused more by the failure of the market than of the supply of fish. The natural history of the pilchard was investigated at Plymouth from 1889 to 1894, and the credit of having carried the inquiries to a successful conclusion and solved the problems which in France were declared to be insoluble in the immediate neighbourhood of the coast, belongs to the Plymouth Laboratory.

Hitherto naturalists have not had the opportunity of studying the occurrence of yearling pilchards on the coasts of Devon and Cornwall in summer time, although there is every reason to believe that they occur there in numbers. But at the end of 1891 a fleet of small-meshed nets, intended to capture anchovies, was shot frequently, and took considerable numbers of small pilchards. These were taken in November and December in numbers varying from 8 to 500. Their lengths were from 5 to 6½ inches. With them were taken others larger and older. The small fish must have been just over a year old, hatched late in the preceding season.

We have now to consider what is known concerning the history of the pilchard between its transformation to the perfect form in one summer, and its appearance as yearling fish the next. Mr. Dunn long ago observed that small pilchards 2 to 3 inches long were to be found on the coast between September and Christmas. He had seen them taken in a mackerel seine in September, and had found them in the stomachs of whiting, In November, 1891, I found them in the stomachs of mackerel; they were from 2 to 3½ inches long, some of them less than 2 inches. These mackerel were caught outside the Eddystone. But in September, 1893, I found that pilchard fry were not found only in the open sea at some distance in the offing. I had an opportunity of examining in that month the fish caught by seine in the Hamoaze, opposite Devonport. The greatest part of the catch consisted of full-grown sprats, but there was also a large quantity of small fish of the character of whitebait. These consisted mostly of young sprats, 2⅛ to 3½ inches long, but among them were a small proportion of young pilchards, 2¾ to 4⅝ inches long. These were probably derived from spawn shed in May or June.

The growth of the pilchard in its second year is of course more difficult to trace. It seems reasonable to suppose that the fish which are 5 to 7 inches long in November, or earlier in August and September, would reach a length of 8 to 10 inches in the following summer, and then spawn for the first time. The only ripe pilchards I have measured were from 9⅖ to 10 inches long, but considering that these were taken in mackerel nets, the mesh of which is large, it is probable that many fish spawn at a smaller size. I have examined specimens from the regular fishing in August, these were from 8⅖ to 10 inches long, and even in the smallest the roes appeared to be shotten, to have discharged their eggs quite recently. We may conclude therefore that some pilchards spawn in their second season when they are about 8 inches long. The weight of a ripe female is 5 to 5¾ ounces.

The Shads.

Allis Shad (*Clupea alosa*) and **Twait Shad** (*Clupea finta*).

Distinguishing Characters.—Dorsal commences nearer to the end of the snout than to the root of the tail ; pelvic fin behind the commencement of the dorsal. Radiating lines on the gill-cover and beneath the eye. Teeth minute and easily detached in both jaws, none on the palate or tongue. The upper jaw deeply notched in the centre, and reaching back farther than the hinder edge of the eye. Scales smaller than in the pilchard ; spines on the edge of the belly strong and sharp.

In the allis shad the gill rakers on the lower portion of the first gill arch are long and sixty to eighty in number ; in the twait shad they are thicker and shorter, twenty to twenty-eight in number. Spots along the upper part of the side, from the upper corner of the gill-cover backwards, are present in both species, but in the allis shad disappear in the larger and older fish.

The allis shad is said to reach 4 feet in length and 8 lbs. in weight, but 2 feet long is its usual limit. The twait shad grows to 16 inches and 2 lbs. in weight.

Habitat.—These are coast fishes, which ascend rivers in order to spawn, and are not taken usually in large shoals in the sea, though as many as 600 of the allis shad have been taken in a mackerel seine. The allis shad is said to be absent from Sweden, and is not mentioned as occurring in the Mediterranean. The twait shad is abundant in the Nile, and elsewhere in the Mediterranean, and occurs on the Atlantic coast northward to Scandinavia. Both species occur in the Severn, and along the south coast of England, also along the east coast to the Firth of Forth and Banff. They occur round the coasts of Ireland.

Food.—From the form of the gill-rakers, and from occasional examination of the contents of the stomach, it appears that they often subsist on minute crustacea, but frequently when they have the opportunity they feed on small fishes, especially young sprats, which were found in the stomachs of eight specimens of the allis shad taken in Plymouth Sound in August.

Breeding.—The time of their ascent up the rivers is mentioned in Day's *British Fishes*, namely, from about the middle of April in the Severn for the twait shad, May to the middle of June for the allis.

But no scientific study of the eggs or the development or history of the young has been made in Britain or Ireland. For accurate information we are indebted to observations made in France and Germany. At Elbœuf, on the Seine, twelve miles above Rouen, there is a hatchery for the artificial propagation of these fish, and it was there that Professor Pouchet studied the eggs in 1889. The eggs of the two species are very similar to one another. They are heavier than the fresh water in which they develop, and therefore sink, but unlike herrings' egg they are not adhesive. They remain free and separate at the bottom of the river, carried down by the stream, or back again by the tide. They are spawned in May and June.

With regard to the structure of the egg it resembles that of the pilchard without the oil globule. The yolk is subdivided, and there is a large space between it and the egg membrane. The latter in the twait shad measures about 4·5 mm. or nearly $\frac{18}{100}$ inch, while the yolk is only 1·75 mm. or $\frac{7}{100}$ inch. The eggs at a temperature of 66° hatched on the fourth day after fertilisation.

The eggs of the American shad (*Clupea sapidissima*) are hatched annually in millions by the United States Fish Commission, and the fish now seems to be almost as completely a product of cultivation as the oyster is with us. The eggs are shed in fresh water, in which they sink, but remain free and separate. The egg membrane is about $\frac{12}{100}$ inch in diameter, the contained egg being about half as wide. The yolk is divided and without oil globule, so that the resemblance to the egg of the European shads is very close.

Recently a careful study of the twait shad in the Elbe has been made by Ehrenbaum, a German naturalist. He found that this species spawned near the mouth of the river, just above the brackish water, below Hamburg, while the allis shad ascends in the Rhine to spawn as far as Basle, and in the Elbe above Dresden. The spawning took place only at night, and the fish rush about during the process so as to make a swishing noise in the water. The egg of the twait shad when first shed before the separation of the membrane was 1·5 to 1·6 mm. ($\frac{6}{100}$ inch), but after the swelling of the membrane its breadth was 4·2 to 4·6 mm. ($\frac{16}{100}$ inch).

The newly-hatched larva is just over $\frac{16}{100}$ inch long. It is extremely transparent, and has no mouth and very little pigment, so that it resembles that of the sprat. Ehrenbaum was able to trace its transformation to the fully developed form, and its history, with considerable completeness.

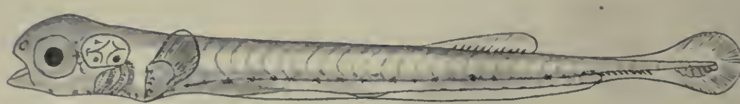


FIG. 93.—Larva of the Twait Shad, nearly $\frac{3}{5}$ inch long; after Ehrenbaum.

The eggs naturally deposited were obtained from the bottom at the end of May by sinking a fine-meshed tow-net. They were quite free, but being so transparent were not easy to find among the rubbish, consisting of fragments of plants, among which they were taken. The larvæ in various stages were captured in the same manner. When 8 to 9 mm. ($\frac{8}{25}$ to $\frac{9}{25}$ inch) long the yolk was nearly all gone, the mouth well developed, and the fin membrane narrow. But the permanent fin rays had not appeared. In June larvæ were obtained which were 13 to

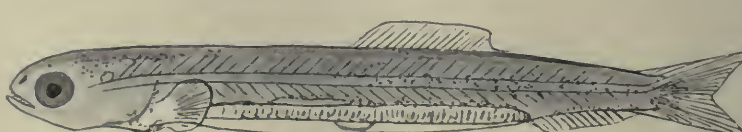


FIG. 94.—Larva of the Twait Shad, $\frac{4}{5}$ inch long; after Ehrenbaum.

15 mm. long (Fig. 93), and in these the dorsal and ventral fin rays had just begun to appear, but the fish was still slender and transparent and the snout rounded. At the end of June specimens 16 to 20 mm. long were taken: in these the forked tail and the fins were more fully developed, and the head was more like that of the adult, but the scales were still absent (Fig. 94). These larvæ were feeding on minute crustacea.

On July 6th specimens were obtained which were 24 to 29 mm. in length, or from a little less to little more than an inch, and which had advanced further in their transformation. The head, and especially the gill cover and also the abdomen, began to show the silvery coating of the fully developed fish, and the pigment of the back was considerably increased ; but the body was still very slender and narrow, decreasing rapidly from the head backwards. The dorsal fin was still behind the hinder side fin in position. By the middle of July young shad, whose transformation was practically complete, were found to be captured in the *stow*-nets, having now become thick enough to be retained by its meshes. These were 36 to 46 mm. long, or from 1½ to very nearly 2 inches. Their body was almost completely silvered, and the scales developed nearly everywhere, the keeled scales of the belly being well formed. The dorsal fin was now in front of the pelvic, and in some specimens the dark spot on the shoulder was visible. It would appear from this that the transformation of the twait shad is a little more rapid than that of the spring herring in the Schlei ; and that the fish at the completion of the process are on the average somewhat shorter than the herring, although the difference is not great.

Young shad from the stow-nets were examined and measured by Ehrenbaum at brief intervals from July onwards, and the following records show the rate of growth :—

July 30, 1893	1·8 —2·8	inches.
August 10, 1892	1·68—2·52	,,
August 15, 1891	2·08—3·12	,,
August 17, 1893	2·16—3·24	,,
September 20, 1893	2·88—4·88	,,
October 6, 1891	2·76—3·44	,,
October 15, 1891	3·08—3·88	,,
November 15, 1891	3·2 —4·96	,,

Records of the number and length of young shads captured in the stow-nets at the mouth of the Meuse in Holland have been published in Dutch fishery journals. To summarise these records, with regard to the twait shad, in the month of October eighty-two specimens were taken, the smallest 2·16 inches long, the largest 6 inches, but the majority 3 to 4 inches. These may be considered the produce of the previous spawning season. In April ninety-three specimens measured 3·56 to 3·68 inches. This shows that some specimens nearly a year old are scarcely bigger than others at five or six months. In June thirty-one specimens were 3 inches to 5 inches. But these results appear to show only the under-sized specimens at one year of age; there must be others from 5 to 7 inches.

Of the allis shad the October specimens, 104 in number, were 2·32 to 5·72 inches, the majority at any rate being fish of the year; the June specimens, twenty-three in number, were 3·84 to to 5·44. The latter must have been a year old, but must also have been very much stunted in growth. The meaning of these results is probably that the young shad, reaching in the case of the twait 3 to 5 inches in November, for the most part leave the river then and do not return until two years of age when they spawn for the first time, and that the few specimens found in the river in their second summer are stunted in growth. In this, as in other cases, more complete evidence is still required.

The Anchovy. (*Engraulis encrasicholus.*)

Distinguishing Characters.—Head terminating in a fleshy pointed snout which projects beyond the jaws; gape of mouth very deep, reaching back far behind the eye. Body slender and elongated, belly rounded without spines on the edge. Scales rather large, easily detached; skin soft and easily torn. Pelvic fins considerably in front of the dorsal; teeth in both jaws, very fine in the lower; also present on the palate. Colour dark greenish along the back, silvery on the sides and belly. The maximum length is 8⅛ inches, the majority are 5 to 7 inches.

Habitat.—Extends throughout the Mediterranean, and along the Atlantic coast of Europe northward to Norway, where, however, it is only taken in small numbers. In winter it is common though not very abundant in the western part of the English Channel, while it has been recorded from the Wash and other places on the east coast in summer. It has been taken in June off Southport in Lancashire, and is sometimes common off Swansea. It has also been occasionally taken on the Irish coasts. In Holland there is a regular and somewhat valuable fishery for anchovies, which is carried on in summer both in the Zuyder Zee and in the estuary of the Schelde. Three methods are employed in these shallow waters for taking the fish, namely, the moored net, a kind of stake net, and a kind of sweep-net.

The moored net is like a small drift-net ; it is about four feet in depth, of considerable length, having the ends stretched on poles. The top line is corked and the bottom line leaded, and the net is fixed by small anchors attached to the poles. The second apparatus is used near Bergen-op-Zoom, and consists of fences, constructed of willow and poplar branches, which lead to gaps at which nets are placed. The sweep-net is a large bag-net dragged along by two boats, each towing one end of the mouth. In France, Spain, and Italy both drift-nets and seines are used for the capture of anchovies, in the usual manner, as for mackerel and herrings.

Breeding. — The anchovy spawns regularly every year on the coast of Holland, in the Zuyder Zee and the neighbouring sea, and also in the Mediterranean. Its eggs and development were first investigated in the Zuyder Zee by a Dutch naturalist. The spawning takes place in June and July. The eggs are buoyant and transparent, but they are unique in shape. Alone among the buoyant marine eggs at present known they are not globular or nearly so, but elongated, sausage-shaped, about $\frac{5}{100}$ inch long and $\frac{3}{100}$ inch broad (1·2 mm. in length, ·7 mm. in breadth) (Fig. 95). Nevertheless, the egg shows its affinity or relationship to those of the pilchard and sprat, having the yolk composed of separate masses as in these ; it resembles the eggs of sprat and shads in having no oil globule. The eggs have also been obtained in the Bay of Naples, where the spawning period is from May to September. The development of the eggs lasts two or three days at a temperature of about 60° to 64°. The newly-hatched larva (Fig. 96) is a little over 2 mm. long ($\frac{2}{25}$ inch), very transparent, with scarcely any pigment, but distinguished from those of other members of the family by the elongation of the yolk. The latter extends from the head nearly to the vent, becoming narrower behind. The mouth is as usual unformed. Thirty hours after hatching the larva is

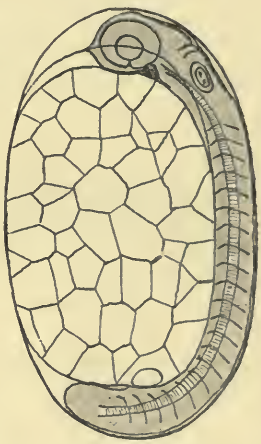


Fig. 95.—Egg of the Anchovy, alive, and magnified ; after Wenckebach.

3·6 mm. long ($\frac{14}{100}$ inch), the yolk is much diminished, and the mouth open beneath the head. On the fourth or fifth days the jaws are fully formed, the yolk exhausted, and the larva begins to feed.

The transformation of the larva has not been very carefully described or figured; in fact, it has not been distinguished with sufficient certainty from the larvæ of other fishes of the family. However, larvæ identified as those of the anchovy were taken July 27th to 31st in the Zuyder Zee; their lengths were 16 to 30 mm. ($\frac{3}{5}$ to $1\frac{1}{5}$ inch).

It has been recorded that young anchovies were taken in the Zuyder Zee in August, which ranged in length from 1·3 inch to 3·2 inches. In September fifty-two specimens were obtained ranging from 2 inches to 4 inches in length; in October thirty-three

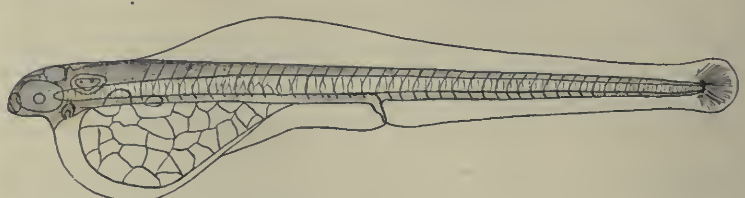


Fig. 96.—Larva of the Anchovy, newly-hatched, alive, and magnified; after Wenckebach.

specimens 3 inches to $4\frac{4}{5}$ inches. It is impossible, unless we had direct evidence that the growth of the anchovy was unusually rapid, to suppose that these specimens were derived from spawn hatched in June and July. The length of the smallest anchovies present in May and June is not stated. We may consider the above specimens as corresponding to pilchards of about 5 inches, and to be the year-old fish. The average length of the mature anchovy is 15 cm. or 6 inches, and the smallest $5\frac{1}{5}$ inches, a size probably reached as in other cases in two years.

We do not know yet the history of the younger anchovies after they are hatched in the Zuyder Zee in June and July. They apparently leave that place in autumn, and return with the full-grown fish the following summer. We have now to consider the migrations of the adults, and see how much remains mysterious in the history of these fish.

It has long been known that anchovies occur with great regularity, but in varying abundance, off the coasts of Devon and Cornwall in the last months of the year. For several years observations on the occurrence of these fish were made by myself and others at the Plymouth Laboratory, and a fleet of small-meshed nets was procured and shot on purpose to catch them. They are usually most in evidence in November. In 1889 a considerable number were taken by the sprat fishermen, fishing with drift nets, off Dover, then they were taken in the sprat seines in Torbay. They continued to be captured till the beginning of January at Torquay. In November, 1890, a thousand of the fish were obtained from the pilchard boats off Plymouth in two days. These facts seem to indicate very strongly that the anchovies leave the coast of Holland in October, and migrate down the English Channel. It would follow that they return to Holland about April. But although a few have been taken by the small-meshed nets off Plymouth in April, they have not yet been found to be so abundant at that time as in November. No indication that any anchovies are present near Plymouth in summer, or that they spawn there, has ever been obtained. It appears then that they move northwards to spawn.

But then the question arises, If the anchovies move northward to spawn, why do not others come up from the Bay of Biscay to spawn in the English Channel? The reply to this apparently is because the shallow enclosed waters of the coast of Holland are much warmer in summer than the waters of the English Channel, and colder in winter. In July, 1891, the mean temperature off Plymouth was 57·3°; in the same month in the Zuyder Zee it was 62·7°. In February, 1892, off Plymouth it was 45·1°; in the Zuyder Zee in the same month 36°. Thus the anchovies are driven south by the cold, and in summer by going to the Zuyder Zee they get water as warm, as it is farther south in the Bay of Biscay, where also anchovies probably spawn; but we do not know the latter fact by actual observation at present.

So far as comparisons have been made at present, evidence of abundance of anchovies in the Channel in November is followed by a large catch in the Zuyder Zee in the following summer. But a small catch in the Zuyder Zee has not always been followed by a scarcity in the Channel. The two years when these fish were most abundant in the Channel were 1889 and 1890. In the summer of the former year the catch in the Zuyder Zee was one of the smallest, in the latter year it was the largest ever known, and in 1891 it was also large. The question therefore arises whether the number of anchovies which pass up to Holland have all been hatched there, or whether they are recruited from the south; that is to say, whether a mild winter allures the anchovies northwards towards the Channel, and they then with the approach of summer pass northwards instead of southwards to spawn. Then again it is possible that the fish may be very abundant off the coast of Holland but not enter the Zuyder Zee.

THE SALMON FAMILY

THE fishes of this family are distinguished by having two dorsal fins of which the foremost is situated near the middle of the back and supported as usual by fin-rays, while the hinder, placed above the ventral fin, is small and imperfect, having no fin-rays. There is a peculiarity in the internal structure of these fishes, which occurs also in the eels, namely, that the roe in the female is not a closed sac, but is as it were split open, so that the eggs when they are ripe become free in the belly cavity before they escape by an opening behind the vent. Different fishes of the family show a great diversity of habit. With one exception in New Zealand all the species are confined to regions north of the tropics, but within this part of the globe some live entirely in fresh water, some feed in the sea and spawn in rivers, while a few live always in the sea, some of these belonging to the abyssal depths of the ocean. In Britain the grayling and river trout, and the pollan, vendace, &c., of the large lakes are the fresh-water forms, the salmon and sea-trout the migratory. The eggs of all these are of considerable size, and are heavy and non-adhesive ; they are buried by the parent fish in the gravel bottoms of rivers or lakes. The smelt lives at the mouths of tidal rivers, and spawns in fresh water some miles from the sea. Only one marine species of the family occurs off British and Irish coasts, namely, the argentine, which has been frequently taken at depths of 30 to 500 fathoms off the west coasts of Ireland and Scotland. As this fish is of no commercial importance, and scarcely anything is known of its habits, and as the species that spawn in inland waters are outside the scope of the present work, the history of the smelt alone will be here considered.

The Smelt. (*Osmerus Eperlanus*).

Distinguishing Characters.—Body elongated, cleft of mouth deep, the upper jaw reaching back to the hinder edge of the eye. Enlarged fang-like teeth, as well as smaller ones on the palate and tongue, ordinary teeth in the jaws. Scales of moderate size. The tail fin forked. Colour of a light olive-green on the back, silvery with iridescent colours on the sides and belly. Along each side there is a specially distinct broad silvery band, brighter than the rest of the side. Rarely exceeds 12 inches in length.

Habitat.—Mouths of rivers in Northern Europe and North America. Its southern limit appears to be the Seine, where it ascends as high as Rouen. It is found in the Thames and Medway, but not on the south-west coast, *e.g.* Plymouth, where a fish belonging to a different family is called the smelt. This is the sand smelt or atherine, which has a close resemblance to the smelt in external appearance. In the rivers of the east coast of England the true smelt is plentiful, and regularly captured for the market. It is found in the Forth and the Tay, the rivers entering the Solway, the Dee, and the Mersey, but is not known to occur in the rivers of Ireland.

Food.—It feeds on small fish and crustacea.

Breeding.—It spawns in March, April, and May, ascending to near the limit of the rise of the tide, where the water is fresh or very nearly so. In the Forth it spawns annually just below Stirling, where I have taken the eggs and fertilised them artificially. More recently the development of the eggs and the history of the young have been carefully studied by Ehrenbaum, a German naturalist, in the Elbe below Hamburg.

The egg is heavy and adhesive, but it is attached to the stones of the bottom, or to wharves and piles in the water, in a manner different to that found in the case of the herring (Fig. 44, p. 93). The egg membrane in the ripe egg consists of two layers, and when the egg is shed by the female fish the outer layer bursts at one point and separates, remaining however connected with the inner layer over one circular patch, in the centre of which is the minute opening by which the sperm of the milt makes its entrance into the egg. The loose outer membrane is sticky when the egg is first shed, and attaches itself to the surface it touches or falls upon, so that the egg remains suspended or anchored by the flexible membrane. Ehrenbaum found however many eggs quite free, having been evidently torn from their attachment, and this seems to happen frequently in consequence of the force of the tidal currents. In the Elbe the fine net used at the bottom always brought up much rubbish, consisting of fragments of water plants, and among this were the smelt eggs, some attached to the fragments, some free.

After fertilisation a considerable space is formed between the enclosing membrane and the body of the egg. The shape is round and the breadth of the enclosing membrane varies from ·9 to 1·3 mm. (about $\frac{4}{100}$ to $\frac{5}{100}$ inch). The yolk is composed of small globules, and contains several oil globules of different sizes. The whole egg is fairly transparent, but less so than marine buoyant eggs.

The development is rather slow and took at a temperature of 46° to 53° twenty-seven days. In the earlier part of the spawning season, from the end of March onwards, the water being colder, the development would take longer. The newly hatched larva is 5·5 to 6 mm. long ($\frac{24}{100}$ inch or a little less). The mouth is already open, but beneath the head ; the yolk is much reduced, and the oil globules all united into one which is situated near the front end of the yolk sac. The primitive fin membrane is narrow, the intestine ends near the end of the tail, far behind the yolk sac as in the larvæ of the herring family. The pigment is very scanty, there is some in the eyes and specks on the yolk sac and along the lower edge of the body. The whole larva is very delicate and transparent.

The larvæ were kept alive for fifteen days after hatching in an aquarium. On the sixth day by the growth of the lower jaw the mouth had become terminal and the yolk was nearly all gone ; but the fins had not begun to appear (Fig. 97). The larva at this age was 6·3 mm. long ($\frac{1}{4}$ inch). The youngest larvæ captured in the river were taken on the 5th to 8th May, were 6 to 8 mm. long (the largest nearly $\frac{1}{3}$ inch), and had already begun to feed on the minute crustacea, called copepods, the usual food of young fishes. The larvæ were extremely abundant in the estuary of the Elbe, a small net only 2 feet 8 inches across the opening placed in the current for a quarter of an hour captured on one occasion on May 28th a number calculated to be 107,000. These specimens were 14 to 20 mm. long ($\frac{3}{5}$ to $\frac{4}{5}$ inch) and were still very transparent, but the first dorsal and the ventral fins had appeared. These larvæ (Fig. 98) were still very slender in proportion to their length, and were remarkable for the great size of the air bladder. In the middle of June the little fish were $\frac{4}{5}$ inch to $1\frac{7}{25}$ inch long, and had nearly reached the form and character of the perfect smelt. They were still however transparent, and without the scales and silvery coat.

Even in August the young smelts, now $1\frac{7}{25}$ inch to $1\frac{4}{5}$ inch, although more pigmented and less transparent, had not acquired their scales and silvery garment. The development of these last characters of the perfect fish takes place in September and October, when the young are 2 inches to $2\frac{2}{5}$ inches

97

98

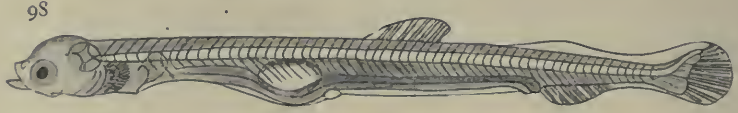


FIG. 97.—Larva of the Smelt, $\frac{1}{4}$ inch long, 6 days old ; after Ehrenbaum.
FIG. 98.—Larva of Smelt, $\frac{3}{5}$ inch long ; after Ehrenbaum.

long. It will be seen from this that the transformation of the young smelt is more delayed and more gradual than in the case of the spring herring, whose change to the form and character of the adult is completed in the Baltic at the end of July.

In August the multitudes of smelt fry of the year become large enough to be caught by the large stow-nets (*steerthamen*) which are used in the Elbe. But these are employed not as a delicacy for the table as whitebait is in London, but only as bait for the eel traps.

After October the smelt, young and old, descend towards the sea, and return towards fresh water at the end of February and in March. In the Elbe Ehrenbaum found that while the smallest ripe fish were 4 inches long, others which were as large as this were immature. He also observed that in the first half of the summer, before the young of the year had got beyond the larval stages, young immature smelt of $2\frac{4}{5}$ to $3\frac{3}{5}$ inches in length were very abundant, and also caught in very large numbers for eel bait. This shows the usual growth of the year-old fish, some of which spawn for the first time when two years old and 4 inches to 6 inches long.

THE EEL FAMILY

THE fishes belonging to this family resemble one another in the following particulars. The body is elongated and usually round, though sometimes flattened from side to side; it is always flattened at the tail end. The vent is some distance behind the head, and behind the vent is a long tail region becoming gradually thinner. The dorsal and ventral fins are very long and flexible, extending either to the extreme tip of the tail or right round it, so that there is no distinction between them and the tail fin. The pelvic or hinder side-fins are entirely wanting, the breast-fins usually well developed. The skin is soft and extends all over the head and gill covers; there are no scales or only rudimentary ones entirely imbedded in the skin. The body is strong and muscular, and extremely flexible. The common eels live in fresh water, but do not breed there; there are several marine forms found near the coasts like the conger, and a number of species inhabiting only the abysses of the ocean. The members of the family are spread through all the tropical and temperate zones, but absent in arctic and antarctic regions.

The mode of propagation of these fishes has always been a mystery, but recently some light has been thrown upon it although it is by no means fully explained. The roes whether hard or soft are difficult to recognise in most specimens, because they are small and undeveloped; but nevertheless they are always present, extending nearly the whole length of the belly cavity on either side of the intestine. The young eggs in the females can be recognised under the microscope even in the narrowest roes. The female organ is band-shaped and not tubular as in most fishes; the eggs are borne along the outer side; there are no tubes to conduct the eggs to the exterior, but they escape by a small opening behind the vent. The eggs when ripe must therefore become free in the belly cavity before they are shed. The male organ, on the other hand, is spongy as in other fishes, and the milt escapes by a tube or duct.

Eggs of the buoyant transparent kind found in the Bay of Naples have been recognised as belonging pretty certainly to fishes of the eel family, but have not been connected with particular species. Only the conger and the fresh water eel occur in the British Isles, and no buoyant eggs which could possibly belong to them have yet been found off the British coasts. The ripe eggs have never been obtained from the fish themselves. The young forms have recently been recognised in certain peculiar, band-shaped, transparent fish previously described as distinct species under the name *Leptocephali*. It is practically certain that both eel and conger spawn only once and then die, and the males are much smaller when mature than the females.

The *Leptocephali* (which means literally small-heads) have some of the characters of the larvæ of other fishes, but they have also many striking peculiarities of their own. Like other fish larvæ they are transparent and have no scales or silvery layer in the skin, and the bony skeleton is not developed.

Their chief peculiarities are the great height of the body from the back to the belly and its remarkable thinness from side to side, the small size of the head, and the large size of the whole creature. The largest specimen described was 10 inches long, but the more usual length is 5 or 6 inches, and some are smaller than this. The vent is usually near to the hinder end of the body. It is remarkable that the great vertical depth belongs to the body itself, and is not due to the presence of a broad fin membrane like that of other fish larvæ. On the contrary, the fin membrane is very narrow or absent, and in cases where a longitudinal fin with rudimentary rays is present, this also is narrow. In the thin specimens there is no red blood, but specimens have been described in which the body was more rounded and red blood was present; in these the whole development was obviously more advanced.

These curious forms have been taken on the English coasts, in the Mediterranean, especially in the Straits of Messina, and in the surface waters of the ocean in various parts of the world within the tropics. They are nowhere common except in the Straits of Messina, where they are caught by boys when bathing.

Evidently their powers of swimming are not great. There are differences of shape and structure among them, and a number of species based upon these have been described. Only one kind has been taken on English shores, and this kind, formerly called the Morris, occurs also at Messina. In England only a few specimens have been taken since it was first discovered in 1763. It is usually 5 or 6 inches long and ½ inch broad.

Various theories were formerly proposed concerning the nature of the *Leptocephali*. In 1861 it was suggested that they were the larvæ of certain fishes which had an elongated narrow band-like form in the adult condition, namely, fishes of the same family as the red band-fish of British waters (*Cepola*). But the anatomical peculiarities, such as the position of the vent and absence of pelvic fins in the *Leptocephali*, did not agree with this supposition, and in 1864 an American naturalist announced his opinion that they were the young of the eel family, and in particular the English form Morris, the young of the conger. Dr. Günther in 1870 expressed his agreement with this view with regard to the derivation of the Morris, from the conger, but was unable to accept the idea that the *Leptocephali* were the natural ordinary condition of the young of fishes of the eel family, because they are so large, and he had seen young conger smaller than the known specimens of the Morris. He suggested therefore that the *Leptocephali* were monstrosities, were larvæ which having got into unnatural conditions had gone on growing in the larval state without going through their proper transformation.

In 1886 however, at Roscoff in France, a specimen of the Morris was kept alive in the aquarium and actually observed to change into the conger, and in 1891 and 1892 Grassi and Calandruccio, two Sicilian naturalists, made very careful and successful experiments on the *Leptocephali* taken at Catania, and actually observed the transformation of different kinds of the larvæ into different kinds of eel-like fishes found in the Mediterranean, including the conger. The difficulty pointed out by Dr. Günther is explained by the fact that the *Leptocephali* take no food during their transformation, and become very much reduced in size. Such a reduction in size during transformation is known in other animals.

The habits of the *Leptocephali* are not fully explained. In the Straits of Messina they are taken in mid-water or near the surface, and the oceanic forms have been taken at the surface. But at Catania they were taken in fine-meshed seines which were dragged along the bottom, and in the aquaria they hid away in groups, making their way into the intricate crevices between and under stones, or any other objects on the bottom or burrowing into the sand: they also sought the darkest corners and retreated from the light. In England the Morris has been taken by the prawn-net worked by hand on the shore, and also occasionally at the surface. But neither in the Mediterranean except at Messina, nor on the Atlantic coasts of Europe have these creatures been taken in the fine-meshed tow-nets so much used by naturalists in the sea. It seems evident, therefore, that these curious creatures live naturally on the sea bottom, but then the question immediately arises, Why are they not taken in the dredge?—a question to which we cannot at present give a satisfactory answer. The larvæ of the eel and conger must be very abundant somewhere. At Messina the reason that the *Leptocephali* come so much under observation is probably that the strong currents of that strait, famous for its reefs and whirlpools among the ancients, dislodge them from their retreats at the bottom and carry them about in the eddies. There is no doubt however about the fact that the oceanic forms are found at the surface, as a regular feature of the surface captures, and it seems probable that these will be found to belong to particular species of the eel family different from those whose larvæ have been studied in Sicily.

The buoyant eggs which it is practically certain belong to fishes of the eel family were described and figured by the Italian naturalist Raffaele at the Zoological Station of Naples. They resemble the eggs of the pilchard more closely than any others, but are larger. They have a compound yolk composed throughout of separate masses, and some have a single oil globule, others 6 to more than 30. The space between the egg proper and its enveloping membrane is large, as in the egg of the pilchard. The size varied from 2 to more than 3 mm. ($\frac{2}{25}$ to $\frac{3}{25}$ in.). That these ova belong to this family is proved by the fact that the larvæ hatched from them have, when the yolk is absorbed, the peculiar and elongated body of the youngest *Leptocephali*, observed by Grassi and Calandruccio. But we know that, as in the case of the pilchard and herring, some fish of a family may have buoyant eggs while the eggs of others develop at the bottom, and, as mentioned above, no buoyant eggs which resemble those attributed to the eel family have yet been observed in British waters where the eel and conger are so abundant. Only two species are commonly found in British waters, namely, the common eel and the conger, but a third, the *Muræna*, is recorded to have been twice taken on the south coast of England. The peculiarities distinguishing the two former are the following.

The Eel: eyes small, upper jaw shorter than the lower, dorsal fin commencing a considerable distance behind the pectoral; small scales embedded in the skin.

The Conger: eyes large; upper jaw larger than the lower; dorsal fin commencing close behind the pectoral; no scales.

The Eel (*Anguilla vulgaris*).

Distinguishing Characters.—Gill openings rather small, eye small, upper jaw not longer than the lower, dorsal fin commencing some distance behind the pectoral. Teeth small, not in rows. The cleft of the gape extends back to the middle or hinder edge of the eye. Small scales embedded in the skin. The colour is dark olive along the back, white or yellow on the belly. The females grow to over 3 feet in length.

Habitat.—The eel is found in all the fresh waters of Europe, except the Arctic regions, the Danube, the Black Sea and the Caspian; it also occurs on the Atlantic side of North America.

Their food is varied, and consists of almost anything alive that they can swallow, and also carrion.

Breeding.—The male sexual organ of the eel was first described by the Italian naturalist Syrski, at Trieste, in 1873; the organ, as seen by him, was not in the ripe condition, but differed from the female organ in being smooth outside and formed of fleshy lobes, in the interior of which were tubes and a main conducting tube opening to the exterior behind the vent. The female organ is a narrow band with folds across on the outer surface, these folds containing the eggs embedded in fatty tissue. Since the discovery of the male organ it has been ascertained that the males are the variety formerly described as the broad-nosed eel, having a broad head and snout. But a more certain distinction is that the dorsal fin commences farther back than in the female, the distance between the commencement of the dorsal and of the ventral being less than the length of the head. Male eels are always smaller than the female, the largest recorded being 1 foot $7\frac{1}{8}$ inches long. They remain more in the neighbourhood of the sea than the females, being found mostly in the brackish water of river mouths, and rarely far above the reach of the tides.

The female eels form the supposed variety called the sharp-nosed eel, the head being narrower and the distance between the commencements of the dorsal and ventral as great as the length of the head or greater. These are found in all rivers as well as in isolated ponds, which they reach by travelling over land. Females have been recorded up to 3 feet 3 inches in length, or even more.

The females migrate down the rivers in October and November, and it is at this time that some of the most productive fisheries are carried on, large wicker-work traps being placed in the river with their mouths directed up stream. A Danish observer has recently published a paper showing that the fishermen and dealers distinguish between yellow eels and silver eels, and that the former are better nourished than the latter, while in these the generative organs are more developed. He concludes that the change in appearance accompanies the approach of the breeding process.

Another difference in the silver eels is the considerably greater size of the eyes, and this agrees with the enlargement of the eyes which I have myself observed in ripe male conger.

There is no distinct evidence that eels ever return after their migration to the sea, and although ripe specimens have never been obtained, nor the eggs discovered, it is most probable that the eggs are shed and develop in the sea, and that the parents die after spawning.

It has long been observed that early in the year, from February to May, young eels ascend rivers. Buckland has described how they pass in great multitudes in a procession about 18 inches wide, close to the banks of the river in the Parrett. They are dipped out with a hand-net, salted, and made into cakes. I have found these young eels on the shore under stones in Plymouth Sound in February and later. They are 2 to 4 inches long, and extremely transparent, except for a black line inside the body along the spinal cord. There is no difficulty in understanding how fresh water streams and ponds are abundantly supplied with eels from the multitudes of young which ascend from the sea.

It must be well understood that these young eels, elvers or eel fare, although very transparent and having no pigment and probably no scales in the skin, are otherwise fully developed, and have the fins and other characters of the adults. But before they reach this condition they pass like other fishes through a transformation which is not yet fully known.

In the course of their interesting researches upon the *Leptocephali*, Grassi and Calandruccio have convinced themselves that one of these forms, previously known as a distinct kind, is the larva of the common eel, as the Morris is the larva of the conger. The form in question, named *Leptocephalus brevirostris*, or the short-snouted *Leptocephalus*, is rather small, not exceeding $3\frac{1}{4}$ inches in length, and $\frac{1}{5}$ inch in vertical breadth. The Sicilian naturalists have not been able to follow the entire transformation on one and the same specimen, but in several individuals kept in confinement they have seen the most important changes, and have traced in a number of specimens a complete series of steps from the *Leptocephalus* to the young transparent eel. The reduction in length during the change may be more or less in different individuals, but it does not exceed $\frac{3}{5}$ inch, so that the smallest perfect eels are 2 inches long. The investigators convinced themselves that young eels with the characters of the adult have never been found less than 2 inches long, so that there is no evidence to contradict their conclusions. But it is a strange fact that the particular *Leptocephalus* which they connect with the eel has never yet been found except in the channel between Sicily and the mainland. The only conclusion to be drawn is that the *Leptocephali* escape capture on account of their powers of concealment. It remains for British naturalists to discover these larvæ in British waters.

It seems at first sight probable that the elvers which ascend rivers in spring are the offspring of the parents which descend the previous autumn. But considering the case of the conger, and the small development of the sexual organs in the eels which migrate to the sea, it seems likely that some months must elapse before the organs are fully developed and spawning takes place. We do not know how long it takes for the larvæ to develop up to the time at which the transformation commences: the latter process in the conger takes a month or little more. It is possible therefore that the elvers when they ascend rivers are about six months old, and are derived from parents which spawned the previous summer, and migrated to the sea the autumn before that.

Eels seem to take some years to grow from the condition of elvers to the mature condition in which they descend to the sea. It has been stated that they take four or five years to reach a weight of 5 or 6 lbs.

The Conger (*Conger vulgaris*).

Distinguishing Characters.—Head and eyes larger than in the eel. Gill openings large. Dorsal fin commencing close behind the breast fins and continued into the ventral round the end of the tail. Mouth wide, the upper jaw slightly longer than the lower: gape reaching back to the middle of the eye. The front nostril tubular. Teeth in a row close together, forming a cutting edge. Colour dark above, light or white beneath. White spots mark the openings of the lateral line. No scales. Margins of the fins black. Light-coloured specimens are often caught: their colour has become lighter because they have been lying on sandy ground. The females attain sometimes to over 8 feet in length and 128 lbs. in weight, but this is rare, probably unique. Specimens between 6 and 7 feet in length and over 60 lbs. in weight are more frequently taken. The small specimens are called 'straps' by the fishermen at Plymouth.

Habitat.—Coasts of Europe, Mediterranean to St. Helena, also in Japan and Tasmania. It occurs in the Orkneys, and is fairly common on the west coast of Ireland, but less common in the North Sea than in the English Channel.

Food.—Fish and squid or cuttlefishes, also crustacæa. It is much given to cannibalism, and the females swallow the smaller males.

Breeding.—The death of large females in aquaria and the great development of the ovaries in them has been repeatedly observed. In large specimens captured in the sea by hook the roes are often found to have a considerable size. I have seen them as much as 3 inches wide with the eggs visible as separate grains to the naked eye. In such specimens the roe is intensely white, and fishermen often deny that it is roe or 'pea,' asserting that it is merely the fat. There is much fat in the roe in this condition, but the eggs are scattered through it and can be recognised without much difficulty. The roes in females which have died in aquaria are larger and the eggs also larger: the fat is entirely absent. The weights of the roes were taken and the number of eggs calculated in the case of females which died in the Southport aquarium in 1876, and in the Berlin aquarium in 1881. In a specimen only 22¼ lbs. weight the total number of eggs was calculated to be over six million by Mr. Jackson of Southport, while in Berlin only three million were calculated in a specimen weighing 22½ lbs., of which the roes weighed 8 lbs. In another calculation given by Buckland, in a conger 6½ feet long weighing 69 lbs., whose roes weighed 7¼ lbs., the number of eggs was over 14 million. I myself calculated the number in a specimen 5 feet 4 inches long, 33 lbs. 8 oz. in weight, whose roes weighed 7 lbs. 6½ oz., at nearly eight million. The death of conger in the same condition, with their bellies distended with the enlarged roes, was also observed at the Naples aquarium.

The male conger was discovered by Dr. Otto Hermes, Director of the Berlin aquarium, in 1880. A number of specimens caught near Havre were sent to that aquarium in 1879: they were 2 feet to 2 feet 4 inches long. All grew rapidly except one which died on June 20, 1880, and was then only 2 feet 5 inches long. When it was opened it was found to contain large soft roes somewhat like those of the herring, and these were full of ripe milt.

My own experiments and observations at Plymouth extended our knowledge of the conger considerably. I confirmed Dr. Hermes' description of the ripe male organs, and examined a number of male specimens alive and dead in the years 1887 to 1890. I found that when a number of small conger, less than 2 feet 8 inches in length were obtained from the fishermen, there were nearly always some males among them. In some of these the soft roes were of considerable size and well developed, in others they were very small, but in no case were they actually ripe. On the other hand ripe male specimens were repeatedly obtained among small conger, under the above limit of length, kept alive in the aquarium. The largest male which I measured was 2 feet 2 inches long, and the smallest ripe specimen 18 inches. I found it was usually possible with some care and practice to distinguish the males from females of about the same size. The chief differences are that the belly of the male is more pigmented than that of the female, that the snout of the male is blunter at the end and flatter above than that of the female. The eyes are larger in ripe males that are kept alive some time in the aquarium, but this is a difference that cannot be relied upon in unripe males. In fact, as might be expected, all the differences are less distinct in unripe specimens, so that it is easy to be mistaken in picking out certain specimens as males. I was able however to select a number of living males and keep them alive until they became ripe, and found that this could be done without any difficulty. Ripe male conger can thus be obtained in a well-appointed aquarium in any numbers desired. I further observed that ripe males do not feed, and that although they continue to live for a long time they become gradually thin and weak. The emaciation of the head causes the eyes to have a proportionally large size and strikingly prominent appearance, which is alone sufficient to distinguish a ripe male to an experienced observer. It need scarcely be said that the ripeness of the males was ascertained by taking them out of the tank and gently squeezing the belly; the ripe milt escaped freely, and was examined under the microscope, so that its nature was ascertained beyond a doubt. One of these ripe specimens lived from December 13th to the following June 24th, when it died. Throughout this time it took no food, and it gradually became very weak, thin, and maimed. On March 7th it still yielded milt, which was quite healthy, and the fish when touched moved with considerable activity. But it was quite blind, one eye being entirely ulcerated, the other clouded and opaque. The skin was torn or rubbed off in places. When it died its condition was still worse.

The males seemed to be less numerous than the females even among specimens of the same size: of thirty-four recorded eleven were males and the rest females, and considering that all specimens over 2 feet 8 inches are females, the numerical superiority of that sex must be very great.

To turn now to the consideration of the females, I made careful observations on some large specimens which lived in the tanks. One of these was noticed in December, 1888, to be somewhat swollen, as though the roes were enlarged, and in March, 1889, she ceased to take food. I several times squeezed this fish, an operation of considerable difficulty effected by placing her head in a sack, and got a few eggs from her which measured nearly $\frac{1}{25}$ inch in diameter: but these eggs were white and opaque and evidently not ripe. This female died on September 10th, having lived without food since the previous March, or about six months. In January 1890, I removed two other females which had ceased to feed, and placed them in a tank with eight males, some of which were quite ripe, and yielded milt on squeezing. It will be seen that the fact that the female ceases to feed while the eggs in the roes are ripening, and doubtless when they are ripe, enables the males to approach her and secure the fertilisation of the eggs: the male which approaches a hungry growing female is pretty certain to be devoured. In the specimens separated for observation it was seen that the females frequently pressed their abdomen against the gravel at the bottom, and especially the region of the vent. The males took considerable notice of the females; one of them rested for days constantly by the side of one of the latter, returning with great pertinacity when driven away. But no spawning took place, one of the females died on March 24th, the other on April 22nd. The day before death they writhed and twisted about on the bottom as though trying to get rid of their eggs. But the eggs examined after the death of the fish were not ripe, they were in the same condition as in the female previously mentioned. They were $\frac{1}{25}$ inch in diameter, and still contained in the substance of the roe.

In these females the intestine and stomach were not only empty but much reduced in size, and all the organs including liver and spleen were squeezed into the smallest possible space by the great enlargement of the roes. In one specimen 4 feet 5 inches long the roes weighed 3 lbs. 4½ oz, the other organs 8 oz. In the other, 5 feet 11 inches long, the roes weighed 4 lbs. 5 oz.

It is very likely that the reason why female congers do not spawn in aquaria is that the depth of water is not great enough. I tried the experiment of putting down two females in a box in the sea, but one female died in the usual condition, and the box was lost with the other.

With regard to the condition of the eggs in females which die in the way described, their size has already been mentioned. The yolk is composed of minute globules, and there is no appearance of distinct oil globules. When placed in sea water they sank to the bottom, and after some time a separation took place between the membrane and the yolk. This indicates how near they are to ripeness, but there is nothing to show whether the eggs are of the buoyant kind or not.

There are two questions of considerable interest arising out of these facts: first, how far is the behaviour of the fish natural and how far due to the confinement; secondly, what probability is there of obtaining ripe eggs from conger? My own conclusion concerning the first is that the behaviour of the conger is in all respects natural except that death is somewhat premature. There can be no reasonable doubt that the conger in the sea ceases to feed about six months or more before spawning, and that during that time, as in the aquarium, the roes are developing at the expense of the fat and substance of the rest of the body. In the sea, however, we must suppose that the fish lives until it has spawned. That it then dies is, I think, certain. In the specimens studied in the aquarium, both males and females, it was found that after death the skeleton was in a remarkably degenerate condition. The bones of the head had lost all their hardness, in consequence of the absorption of the lime from them. They were softer than gristle, and could be cut with a knife like cheese. The teeth had all dropped out except a few which were loose. The flesh was much reduced and the skin often torn, but this happened more in the males than in the females. That a fish which had sunk to such a condition as this could recover its former vigour is impossible to believe. In the sea without teeth and without muscular strength it could not capture prey, and without food it could not recuperate itself. The conclusion is that the conger spawns only once and then dies, and that in the aquarium the female dies a little too soon. The reason for this premature death in the aquarium is probably the shallowness of the water, the fish being adapted to spawn under a pressure of twenty or thirty fathoms. In the same way the soles in the aquarium for some years did not spawn, but expelled their eggs in the dead condition.

There seems no probability of obtaining ripe female conger. In the sea they cannot be caught on hooks because they do not seek food, and they do not come in the way of the trawl because they remain among rocks. The only methods by which they might be obtained are that of keeping them in a cage at the bottom of the sea, and keeping them in an aquarium tank in which the pressure was artificially increased ; both methods involving considerable expense and trouble.

The *Leptocephalus Morrisii* or Morris, which is the larva of the conger, has been described by the older naturalists, but the descriptions and figures are not perfectly satisfactory according

FIG. 99.—*Leptocephalus Morrisii*, the larva of the Conger ; after Couch.

to modern requirements. Fig. 99 is an outline copy of the figure given in Couch's work.

The length of the first specimen described was 4 inches, of others $5\frac{1}{2}$ and 6 inches. Grassi and Calandruccio state that larvæ 5 inches long, are reduced, after the transformation, to congers of 3 inches. The transformation may not take more than a month ; it was observed in 150 individuals, and the creatures were kept alive without difficulty in aquaria or even in tubs. The *Leptocephali*, according to Couch, the Cornish naturalist, are not unfrequently obtained entangled among sea-weed. I never had the good fortune to find any either at Plymouth or elsewhere. But a perfect specimen was obtained at the Plymouth Laboratory in 1894. It was found by a boy on the shore of the Sound. Two were taken in the Irish Survey, in a tow net attached to the trawl beam.

I have found that conger less than 15 inches long are usually not black or dark like the adults, but pale and pinkish in colour on account of the small amount of pigment in the skin. The smallest in my collection was $8\frac{2}{5}$ inches long, and was taken in the beam trawl.

Mr. Jackson, of the Southport Aquarium, found that of a lot of congers taken when only 2 or 3 lbs. weight, one died after about two years weighing 21 lbs. and with greatly enlarged roes, another after four years when it weighed 69 lbs., another after five and a half years when it weighed 90 lbs. The age and size therefore at which the development of the roes takes place are very different in different individuals.

THE GARFISH OR GUARD-FISH FAMILY.

THIS family includes the guard-fish, the skipper or saury pike and the flying fishes. In these fishes there is a single dorsal fin far back, opposite the ventral: behind these there are in the skipper or saury pike a row of five or six finlets as in the mackerel. The pelvic fins are placed far back, as in herring, salmon, &c., but the air-bladder has no connection with the gut. In both garfish and saury pike the jaws are prolonged into a narrow slender beak, longer in the former than in the latter. The teeth are larger in the garfish. It is a peculiarity of the garfish that its bones are green, retaining this colour when cooked. In the flying fishes (species of *Exocœtus*) the jaws are short, but the pectoral or breast fins are very much elongated and enable the fish to sustain short flights in the air. The flying fishes belong to the tropics and the open ocean, but one or two specimens have been obtained on the south coast of England.

The garfish regularly visits the British coast, as well as Ireland and the Orkneys and Shetland in summer, migrating to the more distant sea in winter. It is found from Iceland and Scandinavia to the Mediterranean.

Along the south coast the fish spawns in May and June, and is then often taken in mackerel nets. It has long been known that its eggs are provided with long threads or processes at two opposite points, and these threads are adhesive. But the eggs have never been found after being shed in the natural condition, and it seems uncertain whether they develop at the bottom or float about in bunches formed of a number of eggs sticking together by the threads. Day states that he received from Mr. Dunn a portion of a mackerel net with many eggs of the garfish attached to it, eggs which had been shed by fish caught in the net. But it may be that the fish deposits its eggs naturally in the open water near the surface, and that they stick only to one another without becoming attached to the bottom. On the other hand, the American naturalist Ryder states that the eggs of a kind of garfish sink in sea water. He has observed that the eggs of one female form a cluster by the mutual adhesion and entanglement of their threads.

I have found young garfish among the produce of the ground seine in the Hamoaze in September. They were fully developed, being 4 to 5 inches long and over a year old. The younger stages have been shown to undergo a curious transformation. Thus Couch describes a specimen ½ inch long in which the jaws are scarcely elongated at all, only the lower jaw is commencing to grow out and is longer than the upper. At a little over 3½ inches the lower jaw is proportionally almost as long as in the adult, but the upper jaw is still quite short. The various intermediate stages have been captured at the surface and described, and the connection between these young fish and the garfish fully proved, although when the young fish with the upper jaw undeveloped were first obtained they were described as a distinct kind of fish. In tropical regions there are numerous kinds belonging to this family in which the jaws remain always in the condition which is only temporary in the young of the gar-pike. These are called half-beaks, and some of them live in fresh water and bring forth their young alive.

The saury pike occurs annually on the Cornish coast, and along the south and east coast of Britain is taken but not in abundance. Its eggs have filaments for attachment like those of the gar-pike, but its spawning on British shores has not yet been described.

THE FLAT-FISH FAMILY.

THE three chief peculiarities of the flat-fishes are (1) that the two eyes are on one side of the body, (2) that the upper or eyed side is coloured, the lower side white, (3) that the dorsal fin extends forwards as far as or beyond the eyes, but along the edge of the head, not between the eyes. It is not difficult, if a flat-fish such as a plaice and an ordinary fish such as a haddock are examined together, to see what the real differences are, though probably few who handle flat-fishes daily in the course of business ever trouble to make the comparison. Fishermen, however, are accustomed to distinguish between left-handed and right-handed flat-fishes, and in doing this they place the edge on which the mouth and belly are, towards themselves, as one naturally does in looking at one of these fishes. On this edge also are the gills, while on the other is the brain. It is easily seen that apart from the eyes and colour the upper side and lower side are very much alike, and are really left side and right side. There is a gill-flap on each side, and a breast-fin and a throat-fin. It follows therefore that the two fins which run along the edges of the body are the dorsal or back fin, and the ventral or belly fin, corresponding to those of the ling or tusk. In a turbot or halibut it will be seen that the two sides of the mouth are almost exactly alike in size and shape, so that the peculiarity of the eyes of a flat-fish does not necessarily make the mouth lop-sided. In fact the position of the eyes is due entirely to a twisting of the part of the face containing the eyes, to a bending round of the bridge of the nose, which brings the right eye on to the left side or the left one to the right side as the case may be. The front part of the dorsal fin is on the side of the face, therefore, separating the eye nearest to it from its proper side of the head. In certain flat-fishes, especially the turbot, specimens are occasionally taken in which the dorsal fin does not extend forward in the usual manner, but forms a hook overhanging the eye nearest it, and in these specimens it is easier to see how the face is twisted.

There are no large spines in the flat-fishes in the fins or on the bones of the head, but a small one projects in some in front of the ventral fin. The scales are variously developed ; in some they are present all over the body and have a spiny margin as in the common dab, in others they are rudimentary as in the plaice, in others they are developed into rough tubercles as in the flounder and turbot. It should be noted that in these fishes the great extension of the ventral fin causes the vent to have a position very near the head ; it is further forward than even in the whiting and other fishes of the cod family. The opening of the roes is just behind the vent, also in front of the ventral fin, but the belly cavity being very small the greater part of the roe on each side is situated behind it, between the flesh and the partition of bony spines in the middle of the body.

The following are the British species with their distinctions:—

I. Species with the eyes on the right side, the mouth at the end of the snout, teeth most developed on the blind side.

1. **The Plaice.**—Scales small and embedded in the skin ; bony knobs on the head behind the eyes, red spots on the upper side.
2. **The Flounder.**—Rough tubercles along the bases of the marginal fins, and along the lateral line.
3. **The Dab.**—Scales all alike, with toothed edges, making the skin rough.
4. **The Witch.**—Shape oblong, scales all alike, very slightly toothed on upper side : blister-like cavities beneath the skin of the head on the lower side.
5. **The Lemon Dab.**—Scales small and smooth, skin very slimy, head and mouth very small, colour yellowish brown mottled with large round marks.

II. Species with eyes on the right side, mouth large and jaws similar on the two sides.

6. **The Halibut.**—Scales smooth, lateral line with a curve, size very large.

7. **The Long Rough Dab.**—Scales rough, lateral line straight, size very small.

III. Species in which the eyes are on the right side, the snout projects beyond the jaws, the front margin of the head curved, jaws larger on the lower side, and teeth only on that side: a "beard" of short projections from the skin on the lower side of the head.

8. **The Common Sole.**—Breast-fins rather large on both sides, nostrils alike on the two sides: colour, rows of black blotches on brown ground.
9. **The French Sole** or **Sand Sole** (or Lemon Sole).—Nostril on lower side enlarged: specks instead of black blotches.
10. **The Thickback.**—Breast-fins very small: colour five dark bands across the body on a red ground.
11. **The Solenette.**—Breast-fins very small: black blotches as in the common sole, but in addition a line of black on every fifth or sixth ray in the dorsal and ventral fins.

IV. Species in which the eyes are on the left side, the mouth is large, at the end of the snout, and teeth and jaws are equal on both sides.

12. **The Turbot.**—Diamond-shaped body of large size, no scales but blunt bony tubercles.
13. **The Brill.**—Body more oval, covered with smooth scales.
14. **The Megrim.**—Body narrow and thin, scales rough; eyes very large, and mouth also: colour light yellow.
15. **The Scald-fish** or **Scald-back.**—Eyes and mouth smaller, scales rather large, but the skin is very thin and tears off during capture: the first rays of the dorsal fin much elongated in the adult male, not in the female.
16. **The Common Topknot.**—Scales very rough, marginal fins continued beneath the root of the tail, throat fins united with the ventral.
17. **The One-spotted Topknot.**—Like the last, but having the first dorsal fin-ray prolonged, and a single round spot on the upper side towards the tail: under side very rough.
18. **The Norwegian Topknot.**—A smaller fish having neither the throat fins united with the ventral fin, nor the first dorsal ray prolonged.

Of these eighteen kinds all are used as food except five, namely, the solenette, the scald-fish, and the three topknots.

All the flat-fishes possess in a remarkable degree the power which is present in all fishes, of changing their colour, or the intensity of their colour, in accordance with the tone of their surroundings. On a light sandy ground they become pale, on a dark muddy ground they become almost black. Their habits have been sufficiently described in a previous part of this book.

The eggs of all the British flat-fishes are of the buoyant and separate kind, but it has recently been discovered that those of an American species, the winter flounder (*Pseudopleuronectes Americanus*), are heavy and adhesive, and are best treated in the hatchery by being spread on panes of glass. This fish resembles the plaice and dab, having rough scales like the latter. In Europe even the flounder, which lives chiefly in brackish or nearly fresh water, produces floating eggs, and goes down to the sea to spawn. It is a curious fact that the eggs of most of the right-sided species, plaice, dab, flounder, lemon dab, witch, halibut, and long rough dab, are without an oil globule, while those of all the left-sided species, from turbot to Norwegian topknot, have a single oil globule. The eggs of the soles have a number of small oil globules.

The common character of the newly hatched larvæ is that the intestine ends immediately behind the yolk, and opens on the edge of the fin-membrane. In other respects the larvæ of the flat-fishes are very much like those of equal-sided fishes, and at first they swim near the surface and feed on the minute floating creatures in the same way.

Mention has already been made, in the first part of this book, of the fact that the peculiarities in the position of the eyes and in the habits of flat-fishes are acquired when they are still very small, during the transformation of the larva to the adult condition. The mode in which the extraordinary position of the eyes was brought about gave rise, when the transformation of the larvæ was first discovered, to a lively controversy.

A good many years ago the Swedish naturalist Malm, whom I have previously mentioned, noticed small turbot, plaice, and other flat-fishes in which the eyes were not both on one side of the head, but in various positions which seemed to show that one eye was gradually moving round to the other side, passing over the edge of the head. These fishes were very small, less than an inch long, and Malm concluded that this was the way in which the curious position of the eyes was reached. He was able to prove that in the flounder when it began to develop in

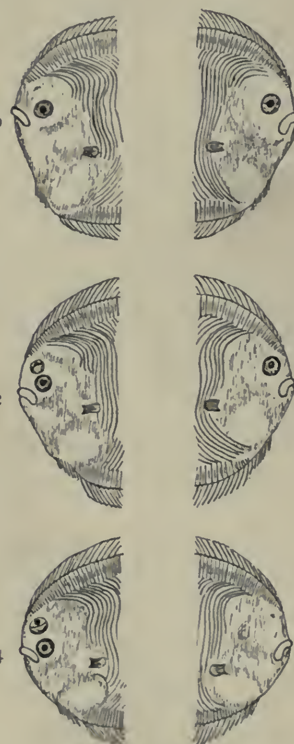


Fig. 100 Fig. 101

Fig. 102 Fig. 103

Fig. 104 Fig. 105

FIGS. 100–105.—The two sides of the head in three different stages in a left-sided young flat-fish in which the right eye passes through the head region to reach the left side (*Rhomboidichthys*). The two upper figures show an eye on each side of the head, but the right eye is higher in position. In the middle figures the right eye is beginning to appear on the left side through a slit above the left eye. In the third figures the passage of the right eye is very nearly completed. (After Steenstrup.)

the egg there was an eye on each side of the head. About the same time, in the years between 1860 and 1870, a naturalist in Denmark obtained some small specimens of flat-fishes in which the eye of the lower side was in various stages of migration through the head, sinking in on one side and coming out again on the other. Figs. 100–105 are copies of the figures which this naturalist published to illustrate the condition of these specimens. He did not find that these flat-fishes were the young of our common kinds, but that, on the contrary, they belonged to a kind which is not taken on our coasts. These two naturalists accordingly had a dispute as to the way in which the eye of the lower side in a flat-fish gets to the other side, one maintaining that the eye went through the head, the other that it went round. The truth was that both were perfectly right, each gave a correct account of what he saw, and formed a true judgment upon it, and neither had any reason to throw doubt upon the statement of the other. The specimens in which the eye was seen on its way through the head were caught in the open Atlantic Ocean by ship-captains. In the year 1878 a naturalist in America actually kept alive specimens of young flat-fishes in some of which the eye went round the head, and in others went through. He watched the little fish while the change was taking place. The facts are now thoroughly well established, and the change in position of the eye in the common flounder and in other kinds can be watched every spring in specimens caught at low tide at favourable places on the coast. In the kind of flat-fish in which the eye goes through the head it is known now that there is very little real difference in the process from that which is more common. In this kind the fin on the edge of the body extends forwards to the snout while the eyes are still opposite to one another, and the eye of the lower side simply tunnels under the fleshy part of this fin, and never actually passes through the bones of the head. In the sole and turbot the fin does not grow forwards to the end of the snout until after the shifting of the eyes has taken place.

The Plaice (*Pleuronectes platessa*).

Distinguishing Characters.—The rough bony knobs on the head are on a bony ridge extending from the ridge between the eyes to the upper corner of the gill opening. The number of fin-rays is not different from the number in the dab: there are sixty-six to seventy-seven in the dorsal, fifty to fifty-seven in the ventral, but the smooth minute scales and the straight lateral line are characteristic. The teeth of the plaice are peculiar, being broad and flat, and ending in straight edges: there are also rounded crushing teeth in the throat. Colour, a number of orange or red spots on a brown ground.

Size.—The largest measured by Dr. Fulton on the east coast of Scotland was 28 inches long. At Plymouth they do not usually exceed 20 inches: the usual size is 15 to 18 inches, the largest 24 inches. The largest measured by Holt on the west coast of Ireland was 26 inches. Farther north they are larger. Mr. Holt found from observations on the Grimsby pontoon that the smallest plaice brought by trawlers from Iceland was 12 inches long, few were less than 17 inches, a great many were 27 inches and specimens of 30 inches or even several inches longer than this were not uncommon. These fish were taken at depths from 7 to 40 fathoms. The colour of these fish as a rule was not so bright as that of North Sea fish, the ground colour being a dark brown, and the spots dull rust-coloured and few in number. On the other hand plaice in the Baltic are limited to a considerably smaller size than those in the North Sea. In a consignment of these fish examined at Grimsby the ripe females were only from 9½ to 13½ inches in total length.

Habitat.—Extends from the Bay of Biscay to the north coast of Europe. Is very scarce in the Mediterranean and absent from the east coast of the United States. It is abundant on the coast of Iceland, and all round the British and Irish coasts.

Food.—The plaice feeds chiefly on bivalve shell-fish, whose shells it is able to crush by means of the strong blunt teeth in its throat, but it also eats sea-worms. In the Firth of Forth, according to the observations of Mr. Ramsay Smith in the Reports of the Scottish Fishery Board, the bivalve most commonly present in the stomachs was a small species called *Scrobicularia*, and next to this in frequency was the razor-shell (*Solen*); cockles, and scallops or clams (*Pecten*) were also present. Of the worms all kinds are devoured, sea-mouse, lug-worms, rag-worms, and tube-worms. Crustaceans in the Firth of Forth were not often among the food, being represented only by an occasional shrimp or crab. Sand-stars were more frequently eaten, fish very rarely.

In opening the stomachs of plaice from the Dogger Bank and the Sylt grounds in the North Sea I have often found them distended with white fleshy masses without any shells. Usually the stomach and intestines of the plaice contain crushed shells which it swallows with the shell-fish they belong to. But in these cases the absence of shells was noticeable. After careful scrutiny I satisfied myself that the fleshy lumps were the so-called "feet" of the razor-shell *Solen*, and it is evident that the plaice is able to seize the "foot" of this mollusc and bite it off. In other cases whole crushed *Solens* were present, but these were usually smaller specimens.

Time and Place of Spawning.—In the North Sea, and in the Channel, the plaice spawns at the beginning of the year—in January, February, and March. At Rothesay, on the Firth of Clyde, according to Mr. George Brook, it spawns in April and May. Off the Isle of May, Firth of Forth, eggs were fertilised by the author on February 3rd. Mr. Holt considers it possible that in the North Sea some plaice are still spawning in April or even in May. At Plymouth none but spent females have been seen after March. On the west coast of Ireland ripe females were taken during the Survey in March and April, but none later until August, and the record of these occurrences in August is probably due to some mistake.

The spawning of each single female occupies a certain time, exactly how long has not been ascertained. It is known that full fish, those which have only just begun to spawn, yield only a few ripe eggs when squeezed, while those which have already shed a good deal of their spawn give up very nearly the whole of the remainder of the crop, and so supply a very large number of eggs. This shows that the rate of spawning becomes faster towards the end. At first a few eggs ripen and are discharged from time to time, but towards the end a much larger number are discharged in a short time. From observation of ripe specimens in the Plymouth Aquarium it is known that a single fish will take several days, from a week to a fortnight or even longer, to get rid of all her eggs.

With regard to the distribution of spawning fish, the places at which they are found, it is known that they are not taken in estuaries or shallow waters near shore, where the younger and smaller fish abound in summer. They are taken in all the deeper waters on shelly or partly shelly ground. The evidence we have, not so abundant as could be wished, indicates that large mature fish visit somewhat shallower waters when not spawning, but remain on rather deeper grounds during the spawning season. We have seen that plaice are not known to occur at all at depths greater than 50 fathoms. The spawning grounds may from our present knowledge be taken to be from 10 to 40 fathoms. The distance from shore varies with the locality. Dr. Fulton found that on the east coast of Scotland plaice do not spawn in territorial waters, that is within the three mile limit, and this is generally true for the south and west coasts of England, and the Irish Sea. But on the west coast of Ireland, where the declivity of the sea-bottom is so much steeper, spawning plaice were found in inshore waters, for instance in Blacksod Bay and the Kenmare River. Smith Bank, 18 to 20 fathoms in depth, 10 to 15 miles off the Caithness shore, has been found in the inquiries of the Scottish Fishery Board to be specially distinguished by the number of plaice spawning there in spring. It is also a good plaice ground at any time, because there are beds of horse mussels upon it, on the smaller specimens of which the fish feed. On the south coast ripe plaice are found on all the usual trawling grounds, along the Cornish coast inside and outside the Eddystone and in the neighbourhood of the Wolf Rock off Mount's Bay.

The eggs, or spawn.—The eggs of the plaice are among the largest floating eggs of fishes known: they are a little less than $\frac{1}{12}$th inch in diameter. Actual measurements by different observers have ranged from 1·65 to 1·95 mm. They can be recognised without difficulty from other similar eggs among a number taken from the sea by means of this large size. The egg is round, the yolk is undivided and without oil globule.

Plaice eggs naturally develop in the sea when the temperature of the water is low, and the development is therefore slow, and it is also slower than that of the eggs of other species even at the same temperature. At the temperature of 53° F. in the Plymouth establishment the eggs hatched in 10 to 12 days. At a lower temperature at Granton in 1886 the development took more than 27 days. The larva when newly hatched is like that of the flounder and dab, but much larger. It is about $\frac{1}{3}$th inch in length. The mouth is not open, the end of the intestine runs down immediately behind the yolk. There are black and yellow specks of pigment on the sides of the body and head, but none on the yolk-sac, nor on the larval median fin.

At Plymouth at a temperature of about 53° the yolk had entirely disappeared, and the mouth was fully developed when the larva was 5–7 days old. Fig. 33 shows the appearance of a living larva in which the yolk is not yet all absorbed.

Abundant and easily obtained as the plaice is in the later stages of its life, and easy as it is to hatch the eggs, the transformation of the larva has not yet been traced out so completely and so certainly as might be desired. Such larvæ have not yet been reared in the aquarium, and in nature the intermediate stages have not come into the hands of naturalists so frequently as those of some other flat fishes. It has been mentioned that at Plymouth the larvæ were kept alive for 37 days, being fed on finely minced worm, and the produce of the tow-nets. But at this

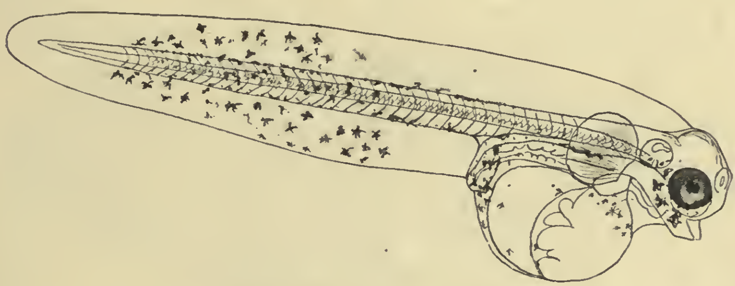


FIG. 106.—Larva of Plaice five days old, alive, and magnified.

age the development of the skeleton had scarcely commenced. In the natural condition there is at present some uncertainty in distinguishing the transformation stages of the plaice from those of the dab, and perhaps other species. The most easily applied test in such cases, as soon as the fin-rays have appeared, is the number of these fin-rays, and in the plaice and dab the number is the same, while the number in the long rough dab, though generally greater, varies so as to overlap the variations in the other two. The plaice has not yet been found in tide pools or at the margin of the sea; until its transformation is complete, its earlier stages have to be distinguished among specimens procured with the tow-net either in mid-water or at the bottom. Fig. 107 represents the magnified appearance in the living condition of a specimen taken near the Mewstone, outside Plymouth Sound, in April 1891. The length was $\frac{3}{5}$ inch, and the specimen was identified as a plaice by its large size.

In the Irish Survey a number of the earlier transformation stages of flat-fishes were taken in tow-nets attached to the trawl-beam in Donegal Bay, at 30 to 32 fathoms, on the 14th and 18th of May. Mr. Holt[1] attributes these to the long rough dab, but distinguishes two series—one of longer specimens, one of shorter. From the excellent figures which he has published I have no doubt myself that the longer specimens were young plaice, and the smaller were dabs. There is a very close resemblance between the figures given by Mr. Holt, and that which is reproduced in Fig. 107.

Later stages, from that shown in Fig. 107 to the fully developed little plaice, were also taken during the Irish Survey, at

FIG. 107.—Larva of Plaice in process of transformation, $\frac{3}{5}$ inch long, alive, and magnified.

depths of 1 to 32 fathoms, in May 1892. They ranged in size from 10 to 21 mm. ($\frac{2}{5}$ inch to nearly 1 inch). The oldest, completely developed specimen could be recognised by its resemblance to the full-grown fish in shape and appearance, and the younger forms were separated from those of the dab by forming them into series leading up to the oldest.

It follows from these observations that the young plaice or larvæ after they are hatched sink towards the bottom during their transformation, and that as they reach the perfect condition they make their way towards shallower water and the shore.

In tracing out or discussing the history and growth of plaice after their transformation from the larval condition it is very

[1] *Scientific Transactions of Royal Dublin Society*, ser. ii., vol. v., Memoir II.

necessary to consider different districts separately, on account of the great differences in the size at which maturity is attained, and consequently in the rate of growth. At Plymouth the smallest mature females are 9 inches long, the largest immature less than 15 inches. The limits in length of the mature and immature overlap one another in this way in consequence of the fact that all individuals do not grow at the same rate or become mature at the same age. The corresponding limits observed at Grimsby were 13 inches and 18 inches, so that there is a difference of about 4 inches between the sizes of plaice when they first become mature in the Channel and in the North Sea. The limits for the males are lower in both districts, but it is doubtful if the observations made were sufficient to determine these limits accurately: they were 9 inches and 13 inches at Plymouth, 9 inches and 16 inches at Grimsby. The difficulty of distinguishing immature from spent males is greater than in the case of females.

It has been proved that the Grimsby limits hold good for plaice throughout the area extending from the English coast to the coast of Germany in an east to west direction, and from the north of Scotland to the Texel in a north to south direction. But along the Dutch coast as far north as the Texel the small Channel plaice extend, the limits of maturity and immaturity being the same in this region as on the fishing grounds off Plymouth.

I have made one experiment, not a very extensive one, on the growth of plaice in the Aquarium at Plymouth. In July, 1893, seven specimens whose lengths varied from 2½ to 3⅜ inches were put into a tank. They were captured at sea, and believed with good reason to belong to the brood of the year, that is, to have been hatched in the preceding spawning season between January and March. In the following October these specimens measured 2¾ to 5¾ inches. In April, 1894, when they were one year old, one of them measured 6¾ inches. In December, 1894, when they were nearly two years old, the only two surviving were 7¼ inches and 8¼ inches in length. These fish were kept in a tank only 5 feet in length and 1½ feet deep, and the number of them was too small to afford evidence of the average rate of growth. But a direct observation of this kind is of great use as a guide in drawing conclusions from the sizes of specimens taken from the sea.

At Plymouth I have not found the young plaice of the year's brood in any great abundance, but have taken some in Whitsand Bay in June. The largest number obtained there in one day by the shrimp trawl was thirty-nine, the depth at which they were caught being 5 to 7 fathoms, and their lengths from 1½ to 2½ inches. Ten specimens obtained by a small seine from the Cattewater in May measured from 4½ to 7 inches in length, and these must be considered as representing the year-old fish. Satisfactory evidence concerning the two-year-old fish is not at present available, but as a very small proportion of females are mature at 9 inches, and a large proportion immature, while three-year-old fish are mostly mature, we may conclude that the female plaice in the Channel at two years of age are about 9 inches and at three years about 13 inches long.

More extensive observations on the sizes and growth of plaice have been made in the North Sea. The great majority of the small plaice taken by the hand-net shrimpers at Cleethorpes on the shore of the Humber estuary at the end of April were found to be from 1½ to 2½ inches long. These must be derived from the spawning period immediately preceding. The experiments on the rate of growth of flounders and plaice, which were made in the Plymouth tanks, are sufficient to show that even Channel plaice must be much more than 2 inches long on the average when a year old, and the North Sea plaice being larger must grow more quickly. We know that multitudes of newly transformed young flounders are found in Mevagissey Harbour, in Cornwall, in April. These are ½ inch long, and after their transformation grow rapidly. The plaice begins to spawn some weeks before the flounder in the North Sea, and we know that millions of plaice eggs are hatched there in January. We are forced to the conclusion therefore that the multitudes of small plaice found at the mouth of the Humber at the end of April, whose average length is 2 inches, are between three and four months old. With them are taken a few larger plaice from 3 to 9 inches long, which of course belong to the brood of the preceding year. The small plaice are equally abundant in May and June, the swarms of little fish appearing on the shore in succession as they are developed from the eggs shed in February and March. In later months plaice of this size get scarcer because they grow larger, but some specimens less than 3 inches in length were obtained in September, and even in January seven specimens of this size were taken in stake-nets near Cleethorpes. These must have been hatched many months before, and serve to show that the growth of a few individuals produced late in the season may be very much retarded. Such observations prove that the remarkable difference in growth among flounders of the same age observed in the experiments made at Plymouth occurs also among plaice in the sea, and it is probably due to the same cause in the two cases, namely competition for food.

A sample of larger plaice taken in the Humber at a depth of one to two fathoms at the end of March varied from 3½ to 11 inches in length, but the greatest number were between 7 and 9 inches. A sample consisting of 425 fish taken by a shrimp trawler at the mouth of the same estuary in May was examined, each fish being measured. The greatest number, namely 265, were from 7 to 8 inches long, those at smaller sizes being fewer. These must be considered as the year-old fish, that is to say, as far as our present evidence goes, we may consider that the length of the largest number of year-old plaice in spring is 7 or 8 inches. By the reasoning previously employed we may infer that the mid-size of the two-year-old plaice in the North Sea is about 13 inches, and of the three-year-old about 17 inches, at the latter size all but a small proportion being mature. These latter estimates apply only to females, the males being smaller.

It is a notorious feature of the North Sea trawl fishery that in the spring and summer months very large numbers of small plaice are taken on what are known in the Humber ports as the "eastern grounds," these small fish being landed at Hull, Grimsby and London. These grounds extend along the continental coast from the Texel to the Horn Reef, and even further northward towards Hantsholm on the coast of Denmark, and from a depth of about five fathoms or even less to fifteen fathoms or a little more. These grounds have a very slight declivity and are for the most part level and sandy. Very few of the small plaice taken on them exceed 15 inches in length and the majority are from 7 to 13 inches. A small proportion of the plaice taken in the trawl are less than 7 inches long, some being as small as 5 inches, though those of this size are not usually taken to market. These remarks apply to the earlier part of the season, from the end of March to the end of June, and samples obtained from the same grounds in November and December contained no fish under 9 inches in length. A box of the small plaice from these grounds and bought for 3*s*. 9*d*. on June 1st, 1895, in Grimsby Market, contained 360 fish, 211 males, and 149 females. The males were $7\frac{5}{8}$ inches to $11\frac{1}{2}$ inches in length, the females from $7\frac{5}{8}$ to 13 inches. From examination of these fish in spring and summer they were found to be with few exceptions immature, and this result has been recently confirmed by examination of large samples taken by German trawlers in winter; all the females, with one exception, under 13 inches were immature, and all the males under 11 inches. It is clear, therefore, that these small fish are not small because they belong to a smaller race, like that in the Channel and in the Baltic Sea, but because they are young and immature. They belong to the same race, and they mature at the same size, as the plaice of the Dogger Bank or the Yorkshire coast. They consist therefore of fish in their second and third years. The remarkable fact about them is their extraordinary abundance, for they are far more abundant than are plaice of similar size at the mouth of the Humber. As far as our present knowledge allows us to judge, the reason for this is the abundance of food on these grounds and the direction of the currents in the North Sea. It has been proved that floating objects are carried southwards and eastwards along the north-east coast of England as far as the coast of Norfolk, and thence in a curved direction to the German Bight, while there appears to be a northerly drift from the Straits of Dover along the Dutch coast. Hence it appears that of the plaice spawn shed in the northern part of the North Sea a greater quantity is carried to the continental shores that to the English. The young plaice brood of the year appears to be reared in enormous numbers on the German and Danish shores, and in spring, the year-old fish seem to move out in a great body from inshore grounds towards deeper water, where they join the two-year-old fish already there, and so constitute the abundance of "small plaice" which have attracted so much attention from those engaged in the trawling industry in the North Sea.

The Common Dab (*Pleuronectes limanda*).

Distinguishing Characters.—To be recognised by the rounded curve of the lateral line above the pectoral fin, and the roughness of the skin due to the spiny scales. The ridge behind the eyes is smooth. Fin-rays, dorsal 65–78, ventral 50–62. The colour is a rather light brown with no distinct markings in the dead fish, but during life spots arranged like those of the plaice, but smaller and not red, can usually be seen.

Size.—On the east coast of Scotland the extreme limits of size of mature females are 5½ inches and 17 inches, of mature males 4 inches and 16 inches. The average size of the males was 8·1 inches, of females 8·9 inches. During the Irish Survey no dabs were taken over 14 inches long. At Plymouth also the average size is 8 to 9 inches.

Names.—Common dab, sand dab, salt-water fleuk (Edinburgh).

Habitat.—From the Bay of Biscay to the north coast of Europe; absent from the Mediterranean and from the American side of the Atlantic. It is abundant on the shores of Iceland, of the Orkney and Shetland Islands, and everywhere around the British coasts, as well as in the Baltic.

The dab has a wide range in depth and saltness of water; it is found in abundance with plaice and flounders in the lower parts of estuaries, though not ascending so far up as the flounder, and it is common in the open sea up to the depth of 50 fathoms. It is more abundant at depths less than 35 fathoms than at those greater.

Food.—From the examination of the stomachs of 579 specimens, taken in the Firth of Forth, it was found that crustacea formed the principal food. They occurred in 48 per cent. of the stomachs. The commonest kinds were hermit crabs of various species, swimming crabs and various "hoppers" (*i.e.* Amphipods). Next in abundance of the animals swallowed were of the class of echinoderms, namely, sand-stars and brittle-stars, which were found in 21 per cent. of the stomachs. Molluscs were less commonly present and included the common clam (*Pecten opercularis*), razor shells (*Solen*), and various other bivalves.

Worms occurred in only 16 per cent. of the specimens, and fish, usually sand-eels and small herrings, in only 5 per cent.

In St. Andrew's Bay the order of importance of the different kinds of prey is different. Here echinoderms and worms form the staple diet, each occurring in 43 per cent. of the stomachs, while crustacea were only present in 22 per cent. and molluscs in 18 per cent. This is an instance of the influence of locality; the bottom of St. Andrew's Bay is entirely occupied by sand and muddy sand, and the most abundant of the lower animals are the sand-stars and the lug-worms and tube-worms (Terebellids).

The females (east coast of Scotland) are both larger and more numerous; the proportion in numbers is 295 females to 100 males, nearly three times as many; in size, 103 to 100—a very slight difference.

Time and Place of Spawning.—On the east of Scotland the majority spawn in April, May, and June, though a few are ripe in February, March, and July. On the west of Ireland the principal months were March, April, and May; on the south-west coast of England the spawning period covers the same three months.

It has been generally observed that ripe dabs in the spawning season occur almost everywhere, there is no evidence of a movement to particular grounds or particular depths at the spawning season. This statement does not apply to estuaries where the water is brackish, and where full-grown dabs are only abundant in summer and autumn, when they are not spawning.

The total number of eggs in three ripe specimens was ascertained by Dr. Fulton; in one $7\frac{1}{4}$ inches long the number was 79,194, in another $8\frac{1}{2}$ inches 128,812.

The Eggs and their Development.—The egg is like those of the plaice and flounder, but smaller than either; it is only ·8 mm. in diameter ($\frac{32}{1000}$ths of an inch), and is therefore one of the smallest of the eggs of the British flat-fishes. Eggs of the dab were artificially fertilised by the author in May 1886, on board a steam trawler six or seven miles to the east of the Isle of May, and developed and hatched in the little Marine Station at Granton. Hatching took place on the third day at the temperature of 45° to 60°, but at St. Andrews at the beginning of May, according to McIntosh and Prince, the larvæ did not escape from the egg until the twelfth day; the difference is due to difference of the temperature at which the eggs were kept.

The newly hatched larva was 2·66 mm. long (a little more than $\frac{1}{10}$th of an inch). Its chief distinction as compared with the larva of the flounder is that the coloured pigment is lighter, being of a lemon-yellow tint instead of chrome yellow. At first there is no pigment on the fin-membrane. Professor McIntosh kept the larvæ alive at St. Andrews for eleven or twelve days, and gives a figure of one eleven days old. The yolk was then all gone, the mouth and jaws were well developed, and there was pigment on the fin membrane. The pigment was present all along the tail, not forming a distinct band as in the flounder.

The subsequent stages of this fish taken at sea are difficult to distinguish with complete certainty from those of the plaice. Numbers of little flat-fishes belonging to one or both of these species in all stages of their transformation from 9 mm. to 32 mm. in length (less than $\frac{1}{3}$rd inch to 1$\frac{1}{3}$ inch) were taken in the month of May during the Irish Survey at depths from 1 to 32 fathoms. They were captured in tow-nets attached to the trawl-beam. Mr. Holt has figured a series of stages considered by him to belong to the dab. They are distinguished from the similar stages of the plaice by the following differences: the fish in the same stage of the rotation of the eyes is longer than the plaice, the body is not so broad in proportion to its length, that is the little fish is more slender in form, and the eye is somewhat larger in proportion to the head. Considering that when first hatched the larva of the dab is little more than half the length of that of the plaice, it is singular that it should be longer than the plaice during the process of transformation. There are no definite peculiarities by which in these stages the plaice and dab can be distinguished. The red spots of the plaice are not yet distinctly developed, and the lateral line is not to be detected, so that the curve in it which distinguishes the older dab is not available. The young flounder can be recognised with certainty by the number of the fin-rays, but the plaice and dab in the adult condition agree in this particular, so that it is of no use to count the fin-rays of the young specimens in order to discover whether they belong to the one species or the other.

In June and July, 1891, twenty-one specimens of the young dab ranging in size from 1·05 to 3·4 cm. ($\frac{4}{10}$ to $1\frac{4}{10}$ inch) were taken in Cawsand Bay and Whitsand Bay, near Plymouth. Small specimens continued to be taken during the autumn and winter until the following April: the size of these was from 1 inch to 3·7 inches, and all could be considered to be derived from the previous spawning, that is to say to be one year old or less. On May 10th in the Cattewater specimens $1\frac{4}{5}$ inch to $3\frac{3}{5}$ inches were taken, and even the smallest of these must have been hatched the previous year. Thus in this species we have evidence as in others that some specimens hatched in one season are found in the following spring at a very small size, having grown very slowly during the autumn and winter.

The following observation on the growth of young dabs in the aquarium was made at Plymouth. From September 29th to October 12th, 1891, forty-eight specimens were collected from Plymouth Sound: they varied from 4 cm. to 6·5 cm. in length ($1\frac{3}{5}$ inch to $2\frac{3}{5}$ inches). They were kept in a tank measuring 5 feet by $2\frac{1}{2}$ feet in area, and 1 foot 6 inches in depth, and were fed on worms, &c. Measured on March 21st, 1892, they were found to be from 5 cm. to 12·2 cm. in length (2 inches to $4\frac{1}{5}$ inches). None of them showed any signs of sexual maturity.

On March 3rd, 1893, twenty-three fish survived in this experiment, and these were measured and examined with the following results :—

There were	fourteen	females	$4\frac{1}{4}$ inches	to	$8\frac{1}{4}$	inches long.
Do.	nine	males	$4\frac{3}{8}$ do.	to	$7\frac{1}{4}$	do.

Two females $7\frac{1}{4}$ and $8\frac{1}{4}$ inches long were ripening, but no others showed signs of sexual maturity: as they were examined only once however during the spawning season too much stress must not be laid on this.

The immature dabs after the larval period are, like the adults, scattered over wide areas and found at nearly all depths. They are not taken in very large numbers in the marginal waters with the young plaice, but with a net of sufficiently small mesh they may be taken at depths of 3 to 35 fathoms.

The food of 175 young dabs $1\frac{1}{2}$ inch to $3\frac{3}{4}$ inches long was examined in Lancashire: the fish were all taken in less than 10 fathoms. Forty-six of the stomachs contained food, in twenty-nine were molluscs, in twelve crustacea, in four worms. The molluscs were chiefly the bivalve *Scrobicularia*, which is common on the Lancashire coast.

The Flounder (*Pleuronectes flesus*).

Distinguishing Characters.—Rough spiny tubercles in a single row along the bases of the dorsal and ventral fins, and about the front end of the lateral line. These are enlarged scales, the other scales are small and smooth, and not projecting from the skin. The head is rather large, like that of the plaice, but without the tubercles on the ridge behind the eyes which are present in the latter. The teeth are conical and pointed. The fin rays are fewer in number than in any other species of Pleuronectes, namely, dorsal 60 to 62, ventral 39 to 45. The colour is a dark brown or nearly black, without distinct markings; the lower side is a brilliant white.

Size.—Dr. Fulton found that ripe males ranged in length from 6 to 14 inches, the average being 8·5 inches; females from 7 to 17½ inches, the average 11·3 inches; the largest female, mature but not ripe, was 18 inches long.

Names.—Fluke is applied to this fish as well as to plaice and dab; in Morecambe Bay it is distinguished as white fluke, in Scotland as the "fresh-water fleuk."

Habitat.—Occurs on the European coast from the Mediterranean to the Baltic and shores of Scandinavia. In the Mediterranean it is usually smooth, the tubercles not being developed, while in the Baltic they are more developed than on the English coast. It is not found on the American side of the Atlantic or in the Pacific.

Of all the British flat-fishes this species is the least marine in its distribution. It belongs essentially to estuaries, ascending into fresh water in many rivers when there are no natural or artifical barriers to obstruct its passage. It is common and in most estuaries abundant, and there is no estuary in the British Islands in which it does not occur. However I know of no instance in which it is found in fresh water cut off from communication with the sea, unless artificially introduced; it can live in fresh water, but as will be explained below cannot propagate in it.

Food.—No very extensive investigation has been made of the contents of the stomachs of flounders; the marine researches of recent years have not been adapted to throw light on this point in the history of this fish. During the Irish Survey twelve adult flounders, 10½ to 15 inches long, taken in Downies Bay, County Donegal, north-west of Ireland, contained sand-eels, one shrimp, several *Idotea linearis* (a common crustacean), and one *Terebella*, a tube-forming annelid. The observations of Mr. Thomas Scott on board the *Garland* were strikingly unfruitful with regard to the food of this species; of seventy-five specimens examined in the Firth of Forth during four years only two contained animals that could be recognised, in one case worms, in the other a *Solen* or razor-shell. The reason of this is simply that the *Garland's* stations were in the seaward part of the Firth, where only spawning flounders could be taken, and when spawning the fish do not feed. Buckland (Report, 1879) states that he found in flounders mussel spawn, by which he perhaps means young mussels, small shrimps and worms in sand. Yarrell gives aquatic insects, worms, and small fishes as the food. In the Plymouth aquarium flounders feed on rag-worms (*Nereis*) and all other marine worms with great eagerness, and will also eat scallops (*Pecten*) and shrimps, and other small crustacea.

Buckland (*loc. cit.*) in describing the flat-fish fishery in Morecambe Bay, says that the flukes are not present there in the winter time, that in frosty weather they, especially the white flukes or flounders, go off into deep water and come back again in fine weather. But it will be found by reference to the reports of the Superintendent of the Lancashire Fisheries District that the migration of flounders in winter is very limited, and amounts to no more than a departure from the marginal grounds between tide marks, to the deeper channels, not a complete removal from the estuaries and bays. This is shown by the fact that although stake-netting for flounders is abandoned in winter, numbers are caught even in January in fish trawls in Morecambe Bay. The most important migration is that of the spawning fish now to be considered.

The male flounders according to Dr. Fulton's data are more numerous than the females, which is the opposite of the usual case among flat-fishes: there are 62 females to 100 males. In size the female is larger, as usual among flat-fishes, the proportion being 126 to 100.

Time and Place of Spawning.—On the east coast of Scotland, according to Dr. Fulton, the spawning period extends from February to the beginning of June, but it is certain that March and April are the principal months. On the west coast of Ireland ripe specimens were found in March, and spent fish in May and June. At Plymouth they spawn principally in February, March, and April, in the sea. They spawn there regularly every year in the aquarium, from the beginning of March to the beginning of May.

Ripe males are occasionally found among specimens taken at the commencement of the spawning season in estuaries, such as that of the Tamar, called the Hamoaze, but ripe females never. In seeking the sea the flounders are limited in their migration, not by a particular kind of ground or a particular distance from shore, but by the saltness of the water. They require to shed their spawn in sea-water, where it will float, although in the Baltic they spawn in water which is considerably less salt than that of the North Sea or English Channel. At Plymouth I have found ripe flounders in great abundance, in the spawning season, on the trawling grounds inside the Eddystone, from about 3 or 4 miles off the land outwards. The depths here are from 15 to 30 fathoms. No flounders are taken on this ground from the end of May to the end of January. Outside the 30 fathom line beyond the Eddystone I have frequently studied the contents of the trawl in March and April, but seen no flounders. Nor have I seen them at the same season of the year on what are called the Mount's Bay grounds, to the south of the Wolf Rock, where the depth is about 40 fathoms. In the Firth of Forth I have taken ripe flounders in Aberlady Bay and it was the only species which I obtained in the spawning condition so far up the Firth. The records of Professor McIntosh's trawling observations in the Report of the Commission of 1885 show that during the spawning period of the fish, flounders were taken at depths up to 30 fathoms along the east coast of Scotland, but not beyond that depth; they were most abundant in the hauls made at 4½ to 10½ fathoms in St. Andrews Bay. On the west of Ireland only one ripe female was taken, and this occurred at 10 fathoms in Kenmare river. In the Irish Sea, according to Professor Herdman's observations [1] spawning flounders were not found in March on the Bahama Bank, east of the Isle of Man, 8 to 10 fathoms, but were found in abundance in the same month in a place called the Hole, just beyond the 20 fathom line. No spawning fish were found in the Lancashire District within the three miles limit, where the depths nowhere reach 10 fathoms; but it seems to me improbable that spawning flounders do not occur in the proper season on that coast between the 10 and 20 fathom line. However the above summary of the evidence available is sufficient to show that we have a fairly definite knowledge concerning the dwelling places and movements of the flounder. It dwells in estuaries ascending high up the rivers and haunting the margins of the fluctuating tides in summer and autumn, retreating to the deeper channels in cold weather, and in February seeking the open sea in order to spawn, but not travelling beyond the 30 fathom line, and about 10 miles from the coast. It is not the character of the food on the outer ground that attracts them, for they do not feed when ripe, and they leave their usual hunting grounds behind them. There is probably some physiological peculiarity in them which renders the expulsion of the eggs difficult in the shallow brackish water, and the female can only get relief from her burden in deeper, salter water. The pressure of the developing eggs probably arouses the desire for greater pressure and greater saltness, and so we get an idea of the instinct of migration in this case as similar to the instinct of taking food to satisfy hunger, to relieve a physiological discomfort.

False notions concerning the breeding of flounders are very common among fishermen. Shrimpers and fishermen who fish in estuaries, and who are familiar with the wide expanses of mud and sand laid bare at ebb tide in such places, usually believe that the lumps of gelatinous spawn which abound over these flats in the spring are the spawn of flounders and plaice. These lumps are of different colours, some green, some pink, some yellow. They are the spawn of the different kinds of marine worms which inhabit the sand or mud, and have nothing whatever to do with fish. In Buckland's Report of 1879, this

[1] Report for 1893 on the Lancashire Sea Fisheries Laboratory. Liverpool, 1894.

erroneous theory is set down on the authority of the fishermen of Morecambe Bay, but in his chapter on the spawning of fishes it is recorded that he hatched some of this kind of spawn from Herne Bay. The fishermen of the neighbourhood asserted most positively that these objects were plaice spawn, but when hatched they proved to be the spawn of a worm. Notwithstanding all efforts at the instruction of fishermen, this false belief was still as tenaciously held as ever among the fishermen of Leigh in Essex, when I lectured there in 1893. Seeing is believing, and it is the invisible character of floating fish eggs which makes it so difficult for fishermen to believe in them.

Another erroneous theory of fishermen is that the flounder carries its eggs on its back. This is known to be true of the Surinam toad, but it is not true of the flounder. This fish in certain rivers where the water is fresh or nearly so, is frequently affected with a curious disease of the skin, which consists in the presence of a number of small tumours, having somewhat the size and appearance of millet seeds. These are both scattered singly and collected in clusters. The disease is mentioned in Day's *British Fishes*, on the authority of Lowe, who observed it in the river Ouse at King's Lynn. It has been described by Professor McIntosh and others in the Reports of the Scottish Fishery Board. I myself saw numerous cases of it among the flounders taken in the stow-nets in the Forth at Alloa. The fishermen there assured me that the little knot-like tumours were the eggs of the fish.

Reversed flounders are very common, that is to say specimens which have the eyes and colour on the left side instead of on the right. Once, on board a trawler, between the Eddystone and the land, I noticed that there were almost as many flounders left-sided as right-sided among a large number caught. The crew of the boat asserted that the left-sided were males and the right-sided females ; but I found that each kind included both sexes.

According to Dr. Fulton's researches, the flounder is the most prolific fish in British seas in proportion to its size (see p. 69).

The Eggs and their Development.—The eggs of the flounder are transparent and buoyant, and only distinguishable from those of the plaice by their smaller size. The egg is from ·95 to 1·03 mm. in breadth (about $\frac{1}{25}$ inch), and is quite round. They are to be taken at sea in the tow-net in February, March, and April, and have been repeatedly fertilised artificially and hatched at Plymouth and elsewhere. The eggs hatched seven days after fertilisation at Plymouth at a temperature of about 53° (12° C.).

The larva when hatched is 2·5 to 3 mm. long (12 hundredths of an inch). The mouth is not open; the pigment is yellow and black, and is absent from the yolk-sac and fin-membrane. A larva two days old (Fig. 59) was found to be 3·56 mm. long (not quite $\frac{1}{7}$ inch). The yolk was reduced to half its original size, and the mouth was nearly but not quite formed. At this stage the pigment had extended on to the marginal fin-membrane, and formed a single broad band across the tail, which is characteristic of the larval flounder. It also formed a less distinct band at the level of the vent.

At six days of age (Fig. 60) the larva was 3·94 mm. long (not quite $\frac{1}{6}$ inch or 16 hundredths), the yolk was all used up, the mouth was formed, and was at the end of the snout. The band of pigment across the tail still remained, the pectoral fin was a large rounded membrane. No indication of fin-rays or skeleton was yet visible.

These stages have been studied from larvæ hatched artificially and kept under observation. The later stages are known from specimens captured on the shore. At many places young flounders in various stages of their transformation, and just beyond it, occur in great abundance in April and May in the shallow pools and channels left by the ebb of the tide. They have been observed and collected at St. Andrew's in Scotland, and at Mevagissey in Cornwall. The species can be distinguished without difficulty by the number of the fin-rays, for these are formed all at once and not gradually: no other flat fish in British waters has so few as forty-five rays in the ventral fin. Fig. 61 shows the structure of one of these young flounders at a stage in which the left eye has not quite reached the edge of the head in its rotation, and Fig. 62 shows the later stage in which the eye is on the edge of the head.

The young flounders in the third period of life, from complete development to maturity, are found in rivers, harbours, and estuaries, which they never leave until they go to sea for the first time, to spawn. Details of the experiments on the rate of growth of flounders have been given in a previous part of this book. The young fish in the estuaries have not yet been very carefully studied. At the mouth of the Humber, below Grimsby, during

Mr. Holt's investigations, a few specimens 2½ to 4½ inches were taken in April and May in the shrimp shove-net and horse-trawl; these could not be the brood of the year, but belonged to that of the preceding year. Older specimens, five to twelve inches long, were taken by the shrimp trawlers.

Professor McIntosh mentions that the food of the young flounders in the period of transformation consists of young *Gammari* (sandhoppers) and similar crustaceans.

The Witch (*Pleuronectes cynoglossus*).

Distinguishing characters.—Head and mouth smaller than in the plaice, eyes rather larger. Body elongated and regularly oval in outline: very thin and flat. No curve in the lateral line above the pectoral fin. Teeth in a single row: points rather blunt. The dorsal and ventral fin with more numerous rays than in any other British species of *Pleuronectes*: 102 to 115 in the dorsal, 86 to 97 in the ventral. Scales feebly spinous on the upper side, smooth (cycloid) on the lower. Colour on the upper side pale brown without distinct markings: lower side with some pigment all over giving it a slightly smoky appearance.

Names.—On the shores of the Firth of Forth, and on the east coast of England commonly known as the witch, a name which is usually spelt whitches in newspaper reports. It is also called the craig fluke, and witch sole in Scotland. It has been called the pole dab, pole flounder, and long flounder by English naturalists. In Dublin it is called the white sole.

Habitat.—Is confined to the North Atlantic, extending from the Bay of Biscay to the north coast of Europe, and on the west side from Iceland and Greenland to Cape Cod. Around the shores of the British Isles, it is rare in the English Channel, fairly abundant in the North Sea, off the west coast of Ireland and Scotland, off the south coast of Ireland, and in the Irish Sea. It is a deep water fish, scarcely ever taken at depths less than 20 fathoms, and ranging to very considerable depths, the greatest at which its capture is recorded being 732 fathoms off the south west of Ireland. Mr. Bourne took one at 200 fathoms, and eight at 70 fathoms. In the lochs of the west coast of

Scotland it has been taken at depths between 20 and 100 fathoms.

Size.—The smallest mature male on the east coast of Scotland according to Dr. Fulton, was 9 inches long, the smallest mature female, 13 inches. The largest male was 19 inches, the largest female, 20½ inches. The average size of the mature males was 14·8 inches, of the females 16·9 inches.

Food.—In the Firth of Forth 150 stomachs containing food were examined. Marine worms occurred in 109, or 72 per cent.; crustacea in thirty, or 20 per cent.; molluscs in twenty-one, or 14 per cent.; echinoderms in five, or 3 per cent.; fish in two. The crustacea were amphipods in sixteen stomachs, common shrimps in ten. It is evident that the most important food consists of worms, and this fact is connected with the small size of the mouth of the fish. On the west coast of Ireland the order of importance of the different kinds of food was the same.

The females are more numerous than the males in the proportion of 260 to 100, and larger in the proportion of 114 to 100. The total number of eggs in the female was found by Dr. Fulton to be from 473,000 to 883,000, a number considerably larger than in the plaice.

Time and place of Spawning.—Off the east coast of Scotland these fish were found to be ripe in May, June, July, and August, principally in July. On the west of Ireland they were spawning in May and June. In the Firth of Clyde they were found to be spawning in June. It has not been shown that these fish repair to particular spots in order to spawn; it may be said that the spawning grounds are simply the grounds where the adult fish are found. On the east coast of Scotland no spawning fish were taken within the three mile limit, but this is not true for other coasts. In the Firth of Clyde a number of ripe specimens were taken between Millport and Fairlie.

The eggs have been studied at Millport and in the Irish Survey. They measure from 1·15 to 1·19 mm. across, and are usually quite round; in character they are not different from those of the plaice, flounder, &c. At temperatures varying from 53° to 68° hatching took place on the sixth day; at lower temperatures some hatched on the ninth day after fertilisation.

The newly hatched larva is 3·99 mm. long (a little less than ⅙ inch). It resembles the larva of flounder and dab, but has less pigment—none on the fin-membrane. As the yolk is absorbed the larva grows very long and slender, and the pigment, developing on the fin-membrane as well as on the body and tail, forms five transverse bands, as in the lemon dab—two on the body and three on the tail. These bands are well marked in the larva when two days old (Fig. 108), when the yolk is not all gone, and the mouth is not yet open; at this age the larva was 5·9 mm.

FIG. 108.—Larva of the Witch or Pole Dab, two days old, alive and magnified.

long (nearly ¼ inch). The coloured pigment is a pale chrome-yellow. Mr. Holt kept the larvæ alive fourteen or fifteen days after hatching. When about ten days old the larva had exhausted the yolk; the mouth was open and terminal, the jaws being well developed, the lower jaw projecting beyond the snout.

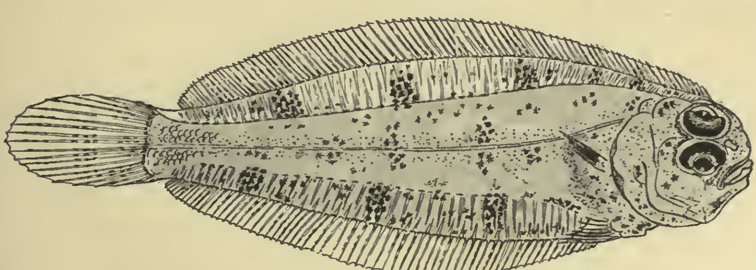


FIG. 109.—Young Witch, a little over 1⅗ inch long, from a preserved specimen. After Holt.

The later larval stages and transformation stages in this species have not been seen either in specimens reared in confinement, or in specimens recognised with certainty from the sea. During the Irish Survey three or four young specimens, which had already reached the perfect condition, were taken in the shrimp-trawl off the Skelligs from a depth of 80 fathoms. These were a little more than 1⅗ in. in length, and were obtained on

Aug. 19th (Fig. 109). The age of these specimens is difficult to estimate, but it seems quite reasonable to suppose that they had been hatched the same season, and were only three or four months old. The number of fin-rays in them agreed with those of the adult, namely, in one specimen, dorsal 105, ventral 89. On the blind side the characteristic pits in the bones of the head which occur only in this species, were already present. The pigment still showed the three bands across the body, behind the abdomen, which are present in the larva.

Three specimens considerably larger were trawled during the same survey at 144 fathoms, in July. These were from 12·5 cm. to 15 cm. in length ($4\frac{7}{8}$ to $5\frac{7}{8}$ in.), and must have been in their second year. These specimens, and still more the smaller ones previously mentioned, are somewhat narrower, in proportion to their length, than the full grown fish.

In the special investigations of the Scotch Fishery Board on the places where immature fish occur, only two immature specimens of the witch were taken. One was 9 inches long, the other 11 inches, and they were taken at a depth of 20 fathoms, ten miles from the coast. It will be seen that as far as the scanty evidence goes, the young stages of the life of this fish are passed in deeper water than that affected by the adults.

The Lemon Dab, or Lemon Sole (*Pleuronectes microcephalus.*)

Distinguishing Characters.—The most obvious peculiarities at first sight are the colour and shape, the former a rich brownish yellow, marbled with round and oval spots of darker or lighter colour, the shape a regular oval. The head and mouth are very small. The fin-rays are dorsal 85–93, ventral 70–76, more numerous than in the plaice, but not so numerous as in the witch. The teeth are conical, rather narrow and blunt. The scales small and smooth, slightly more developed than in the plaice, and extending all over the body and head, and on the fin-rays on the upper side. The lateral line makes a slight curve above the breast fin, but much less than in the common dab.

Size.—It is not a large fish. Dr. Fulton's largest for the east coast of Scotland was 18 inches long. At Plymouth the largest female measured 17 inches, the largest male 16 inches. On the west coast of Ireland the greatest length observed was 15 inches.

Names.—On the east coast of England and Scotland, this fish is commonly known to fishermen and fish merchants as the lemon sole. At Plymouth it is always called the merry sole, which seems to be a corruption of Mary sole, but what was the original reference to the Virgin Mary, which seems to be implied by the latter name, we do not know. In some parts of Ireland it goes by the name of slippery dab, which is very appropriate. Yarrell called it lemon dab or smear dab. It has also been called smooth dab, and, in Edinburgh, sand-fleuk. Since it has no right to claim near kinship with the aristocratic sole, lemon dab is the best name to use for it.

Habitat.—This fish is a northern species, absent from the Mediterranean, but distributed from the Bay of Biscay to Iceland and the north coast of Europe. Adults were not found on the west coast of Ireland at greater depths than 40 fathoms, but the young were found at 80 fathoms, and Dr. Günther has recorded adult specimens from depths of 40 to 60 fathoms, on the north-west coast of Scotland. In his remarks on the trawl fishing off the south coast of Iceland in 1892, Mr. Holt states that lemon dabs were very scarce. Off the east coast of Scotland, they are fairly abundant. According to Professor McIntosh's observations for the Beam-Trawling Commission in 1884, these fish were plentiful on Smith's Bank, off Caithness (18 to 20 fathoms), in Aberdeen Bay, off the Isle of May and St. Abb's Head. In the North Sea, south of the latitude of St. Abb's Head, lemon dabs are fairly abundant, and on the Channel trawling grounds they form a considerable as well as valuable part of the catch. Off the west coast of England they are fairly common. On all these coasts they are usually more plentiful on the deeper grounds some distance from the land, at depths between 20 and 40 fathoms.

Time and Place of Spawning.—In the North Sea Mr. Holt found that lemon dabs were spawning from the latter part of April to the early part of September, nearly five months of the year altogether. He found no spent fish until the latter part of August. The ova of each single female are shed in successive lots, the production of which occurs at intervals. Further north ripe females were observed by the author east of May

Island on May 22nd, and by Prof. McIntosh in August. On the south-west coast the author obtained a few ripe eggs from March 5th to 8th. Fertilised eggs were obtained throughout April and May. Spawning commences in February, many ripe females having been observed in the market on February 18th, and one was also observed as late as July 15th. March, April, and May are however the principal months on the south-west coast, so that the spawning is there two months earlier than on the north-east coast.

No special grounds have been yet observed to be preferred by lemon dabs in the spawning condition. The ripe specimens are found on the grounds on which the adult fish are taken at other times of the year. These fish have not been found to move towards shallower inshore waters after the spawning season, as plaice and soles and other kinds do to a certain extent.

The Eggs.—The egg of the lemon dab is spherical and measures after fertilisation from 1·36 to 1·44 mm. according to observations at Plymouth ($\frac{54}{1000}$ to $\frac{57}{1000}$ inch, or a little more than $\frac{1}{20}$ inch). It is smaller than that of the plaice but larger than that of the flounder or dab. It can scarcely be distinguished from these other species except by its size, resembling them in the undivided yolk and absence of oil globule. Considerable attention was devoted to the study of these eggs at Plymouth in 1888. The temperature of the sea in April and May, near the Eddystone and the Wolf Rock where the fish was spawning, was from 43·5° to 50°. At a higher temperature in the laboratory, namely 53° to 55°, the eggs hatched six days after fertilisation. In the sea their development would probably have taken eight or nine days. In more northern waters the time required would be somewhat longer. The specific gravity of the eggs was found to be about 1·024 ; in water of density 1·025 they floated, in that of density 1·023 they sank to the bottom. The density of the water about the Eddystone at the temperatures above given was 1·0267.

The Larval Stages.—The larva when first hatched is 3·8 mm. in length ($\frac{152}{1000}$ inch, or nearly $\frac{1}{7}$ inch). It is somewhat narrow and slender in shape. The pigmentation is slight, and consists of very light yellow and black specks. There is no definite arrangement of these, they are scattered over the primitive fin, the sides of the body, and the yolk sac. Fig. 110 represents a larva two days old. As the larva develops with absorption of the yolk the pigment becomes more abundant, and by the time that all the yolk has disappeared it has fallen into a definite arrangement consisting of five bands across the body. One of these is behind the eyes, one in the region of the vent, and three on the tail. Each band is not continuous but formed of separate patches, three in the hinder bands, one on the body, and one on the edge of the primitive fin above and below. No trace of such bands has been made out in the adult fish.

The next stage known in this species is that of a specimen secured in the bottom tow-net off Tory Island, north-west of Ireland, at 29 fathoms, during the Irish survey. The fish is identified by its general appearance, and the presence of bars of pigment like those described in the previous stage with an additional patch at the end of the tail. The jaws are well

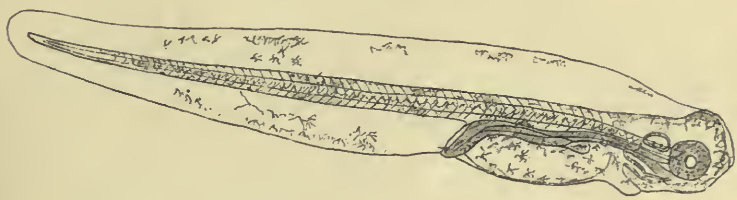


FIG. 110.—Larva of Lemon Dab, or so-called Lemon Sole, two days old, alive and magnified.

developed, and the abdominal region is shortened. The two sides are still alike, except that the left eye has just begun to move towards the edge of the head. The primitive fin above and below the hinder region of the tail remains without bones, but there is a commencement of the formation of the fin-rays of the tail at the hinder end on the ventral side. This specimen was 10·37 mm. long (just over $\frac{2}{5}$ inch). It was taken in the month of April. A number of specimens of an older stage were taken in the shrimp trawl at 80 fathoms in August off the Skelligs, south-west of Ireland. These were about 27 mm. long (just over 1 inch) (Fig. 111). They had almost completed their transformation, and were recognised as young lemon dabs from their resemblance to the adult, and from certain of the distinguishing characters which were already developed—for instance, the number of the fin-rays. The shape of the body was characteristic, the peculiar oval shape of the lemon dab. The left eye had not reached its final position, but was on the edge of the head. The pigment formed five well-marked bands across the body as in the stages previously described. These bands were scarcely indicated on the central region of the right side, but marked by distinct patches on the outer parts and on the fins. The fin-rays were well developed in all the fins—the pectoral, the pelvic, the dorsal and ventral, and the tail fin.

These fish are probably from two to three months old. It is remarkable that none of these later larval or transformation stages have ever been taken except on these occasions during the

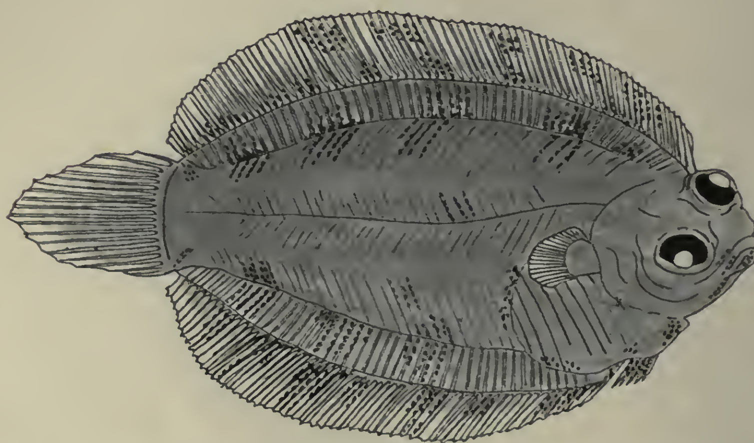


FIG. 111.—Young Lemon Dab in last stage of transformation, slightly more than 1 inch long. From a preserved specimen; after Holt.

Irish Survey. Corresponding stages of other kinds of flat fish are to be obtained without much difficulty at the margin of the sea in harbours, estuaries, or bays at low tide. But no specimens of the lemon dab in these stages have been found in such situations. It need not be concluded however that they only occur at depths approaching 80 fathoms. On the south-west coast of Ireland the declivity of the bottom is very rapid, and it is highly probable that in the English Channel or the North Sea the later larval stages of the growth of this fish are passed on grounds only somewhat deeper than those where the adults live. They may be even on the same grounds. It is to be remembered that such minute specimens are only to be taken with a shrimp trawl, and that the opportunities for the use of this trawl by naturalists in deep water at some distance from the coast have been very limited.

For some time specimens of the lemon dab in the third stage, from complete development to sexual maturity, were almost as unknown as those in the developing or second stage. In the course of the extensive trawlings of the *Garland* with a small-meshed trawl, Dr. Fulton only obtained three specimens 2 inches long, and these were taken on the Smith Bank, at a depth of 20 fathoms, in March and May. It may be noted that these specimens must have been hatched in the preceding year, since there had been no spawning the previous autumn and winter. They must have been, therefore, at least six months old, and may have been ten to twelve months.

Recently, however, immature lemon dabs have been discovered in large numbers on inshore grounds. In the beginning of October, 1892, Mr. Holt obtained a few small specimens from the Humber estuary, and subsequently, when trawling from a steam yacht between October 19th and November 17th, he obtained some specimens in almost every haul. The largest number in one haul was sixteen, others yielded eleven or twelve, others not more than seven. The usual size of these was 2½ to 3½ inches, a few were of larger size up to 8½ inches, and one was 11 inches long. It is impossible to be quite certain as to the age of these fish. The experiments on the growth of the flounder have shown that a fish twelve months old may be no larger than another at six months. The lemon dab, in the neighbourhood of the Humber, begins to spawn at the end of April. Comparison with the flounder shows that fish spawned then might possibly reach a length of 2½ to 3½ inches by the end of October. But it is also possible that these fish were at the beginning of their second year. On the whole with regard to the smallest fish it is more probable that they were derived from the preceding spawning season.

At the beginning of June, 1894, the author, taking a trip on board a shrimp trawler belonging to Brightlingsea, in Essex, was surprised to find among the small fish captured in the trawl a very large number of young lemon dabs. The ground fished was in the Wallet, the first haul being just outside Colne

Bar, not far from the shore, at a depth of 2 to 5 fathoms. Two other hauls were taken further eastward with a similar result. The lemon dabs were 3 to 5 inches long, and there were a few larger fish of the same species, but the number of these was insignificant. With the lemon dabs were also taken hundreds of small soles of the same length, and a large number of plaice and common dabs of corresponding sizes. There can here be no reasonable doubt that there was a large assemblage of year-old fish feeding at the bottom of this inshore, almost estuarine, channel. Whether the occurrence of yearling lemon dabs at this particular locality is exceptional or not we do not yet know. At present the observation, as far as this species is concerned, is unique.

The Halibut (*Hippoglossus vulgaris*).

Distinguishing Characters.—Body thick and narrow, approaching to the shape of an upright fish. Dorsal and ventral fins rather narrow, especially in front and behind: both end at some distance from the tail. Dorsal commences above the upper eye. Mouth large: teeth on both sides of the jaws, a double row in the upper jaw. Skin smooth, scales without spines (cycloid). Colour, nearly uniform dark olive, with a slight marbling of darker. Lateral line with a curve above the pectoral fin.

Size.—The halibut is by far the largest of all the flat fishes, not only of Europe but of all the world. Specimens are said to have been taken which were nearly 20 feet long. European specimens 7½ feet long and weighing 320 lbs. have been authentically recorded. Specimens from six to seven feet long are common in the Grimsby market, though the majority captured range from two to six feet.

Names.—Generally called halibut or holibut, which latter is the usual pronunciation on the east coast of England. Called turbot in the Moray Firth.

Habitat.—It is a northern, it may almost be said Arctic, fish. In Europe its southern limit is the English Channel. It probably exists all along the southern shores of the Arctic Ocean—European, Asiatic, and American. It is known to occur off the coasts of Spitzbergen, Norway, Iceland, Newfoundland, Alaska, California, and Kamtchatka. It thus occurs on both sides of the North Atlantic and North Pacific. It is most abundant at considerable depths, 50 to 120 fathoms. The chief sources of the supplies of halibut landed at Hull and Grimsby are the Iceland and Faröe banks, where they are caught with long lines. They are carried alive in the wells of the vessels, each being tied by the root of its tail to facilitate removal when the fish reaches port, and because by this method a larger number can be kept alive. Off the east coast of Britain halibut are fairly plentiful as far southwards as the Great Fisher Bank, and a few are taken on the shallow grounds off the German and Dutch coasts. Single specimens have been occasionally taken off the coast of Cornwall. During the Irish Survey three specimens were taken, two on long lines, one in the large beam trawl, in depths of 17 to 35 fathoms. They were fairly large specimens, 29 inches to 3 feet in length.

Food.—The halibut feeds on fish and crustaceans.

Time and Place of Spawning.—At Grimsby Mr. Holt observed a ripe female in April and one in August, but noticed fish in September whose condition seemed to indicate that they would have spawned in autumn ; these were from Iceland. On the west coast of Ireland a spent specimen was observed in July. On the testimony of Fishery Officers on the east coast of Scotland ripe specimens occurred in March, May, and June, From this evidence we may conclude that the fish spawns from April to August, and that the period may be somewhat extended in both directions.

The Eggs.—The character of the ripe and fertilised eggs has only recently been discovered. On April 30th, 1892, Mr. Holt obtained some ripe ova by pressing the abdomen of a female in the market at Grimsby. The eggs were dead, but the transparency and uniform character of the yolk showed that they were ripe. These eggs were 3·07 to 3·81 mm. in diameter (the largest over $\frac{15}{100}$ or $\frac{3}{20}$ inch). The yolk was like that of the plaice or flounder, colourless, transparent, and undivided, and there was no oil globule. It was evident that the eggs were of the floating kind, although not being alive they did not float. No floating eggs so large as this have yet been taken in the surface nets at sea, probably because such

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nets have not been worked at a sufficient distance from the coast, in the proper regions. Mr. Holt suggests that the egg when alive in sea water may develop a large space within the enclosing membrane, as in the egg of the long rough dab, which is closely allied to the halibut. The egg-membrane was very thin and easily burst. Subsequently in the same year Prof. McIntosh examined two samples of ripe eggs of the halibut, one sample taken at Peterhead from a fish which had been three days on board, and which had been captured on Bergen Bank about 60 miles off the Fair Isle. The fertilised eggs have not yet been obtained, nor any of the larval or very young stages. From observations made in Grimsby market Mr. Holt found that the smallest ripe males were 30 inches long, the smallest females nearly ripe were 43 inches long.

The Long Rough Dab (*Hippoglossoides limandoides*).

Distinguishing Characters.—Resembles the halibut in shape, but the head is broader in proportion to the body. It differs from the halibut in having a rough skin, the scales being furnished with spines on their hinder edges. The mouth is large, the jaws nearly equal on the two sides of the head. Teeth pointed, one row in each jaw. Lateral line straight, having no curve above the breast-fin. The eyes are larger in proportion than those of the halibut. The colour of the upper or right side is a brownish-gray, usually without any spots or markings.

Size.—Dr. Fulton found that off the east coast of Scotland the smallest ripe male was 5 inches long, the largest 8 inches, but nearly ripe males were from 4 to 12 inches. The average length of mature males was 6·5 inches. The smallest ripe female was 5 inches long, the largest 16½ inches, the average length was 8·8 inches.

Names.—It is sometimes called simply the rough dab, but no other local names have any importance. It is known as smeareen in Dublin, long fleuk and sand-sucker in Edinburgh.

Habitat.—Like the halibut this is a northern fish, rare in the English Channel, but extending to the Arctic shores of Europe, and to all the shores of the Arctic Ocean. It is an inhabitant of rather deep water, being rarely taken on grounds less than 20 fathoms below the surface. It does not however descend to great depths, 80 fathoms being the greatest at which it was found on the west coast of Ireland. In the North Sea it is not found on the Dogger Bank or on the shallow grounds of the eastern side and south of the Silver Pit. It is common along the east coast of Scotland and north-east coast of England, occurs in small numbers on the deeper grounds off Mount's Bay and the mouth of the Bristol Channel. It was found by Mr. Holt to be common in the produce of the beam trawl on the grounds off the south coast of Iceland up to a depth of 40 fathoms.

Food of the Adults.—In the Tenth Report of the Scottish Board are given the results of the examination of the contents of 569 stomachs from the Firth of Forth. The different kinds of marine animals were found in the following percentages of stomachs:—crustacea in 49 per cent.; echinoderms in 29 per cent.; fish in 14 per cent.; marine worms in 9 per cent.; molluscs in 6 per cent.

Among the crustacea, the common shrimp was present in 126 cases, hermit crabs in forty-five, swimming crabs in thirty, red shrimps in twenty-one, opossum shrimps in twenty-two.

Among echinoderms, sand-stars occurred in sixty-one, brittle-stars in thirty-five, common starfishes in seven.

Of fish, gobies occurred in seventeen, whitings in five, long rough dabs (cannibalism) in four, and others in smaller numbers.

The most important prey of this fish in the Firth of Forth therefore is the common shrimp, other crustacea come next in order, and echinoderms next

In St. Andrews Bay on the other hand, the echinoderms predominated. Only sixty-two stomachs examined contained recognisable remains, and among these forty-nine contained sand-stars and brittle-stars. Shrimps were found in eleven, fish in five, and worms in two.

Time and Place of Spawning.—Dr. Fulton found that these fish were spawning from February until May, chiefly in March. On the west of Ireland ripe fish were taken in April and May. On the east coast of Scotland spawning takes place both inside and outside the three-mile limit, but chiefly outside.

The Eggs and their Development.—The buoyant ova of this species are common off the east coast of Scotland, and became familiar to naturalists long before it was known to what fish they belonged. At the latter end of March 1885 and 1886, the author obtained eggs about ten miles east of the Isle of May, which were distinguished by the great width of the space within the egg-membrane. At that time no other floating eggs having this character had been seen. The egg proper within the enclosing membrane was similar to that of plaice or dab, having a simple yolk without oil globule. The breadth of the whole egg,

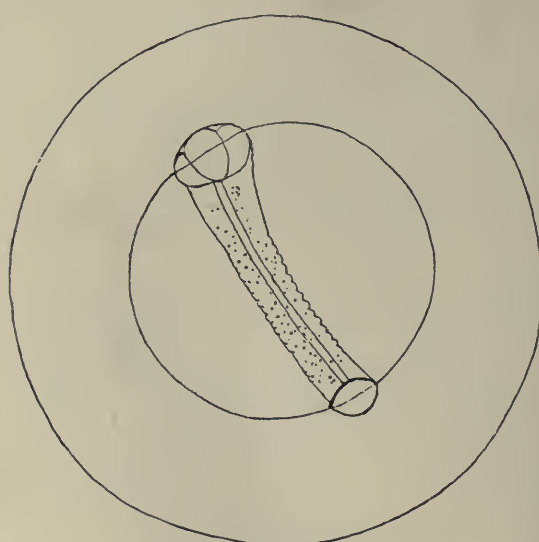

FIG. 112.—Egg of the Long Rough Dab, alive and magnified.

that is of the spherical membrane, was 2·1 mm. (just over $\frac{1}{12}$ inch), a little greater than that of the plaice egg. But the egg proper within the membrane was only 1·2 mm. (about $\frac{1}{20}$ inch). In the memoir of McIntosh and Prince, published in 1889, the egg is again described, and also the larva hatched from it, but its parentage had not been ascertained. The ripe eggs of the long rough dab were obtained from the fish by Mr. Holt on April 9th, 1891, outside Galway Bay, and were artificially fertilised. He found that they were the eggs previously distinguished by the peculiarities mentioned above (Fig. 112). There is no doubt that when the eggs are shed from the roe of the fish, the membrane closely envelops the yolk, and the wide space separating the two is produced when the eggs come into contact with the sea-water. The eggs were not hatched during the Irish expedition, but stages of the larva are known from the work of Professor McIntosh and Mr. Holt at St. Andrews.

In the embryo before hatching there is not much black pigment: the coloured pigment is a pale yellow, distributed somewhat uniformly over the head, body, and tail region, but absent from the yolk sac and marginal fin-membrane.

The newly hatched larva is described and figured by Professor McIntosh in the Seventh Report of the Scottish Fishery Board, 1889, but he gives no measurements. According to Holt's observations the egg was nearly ready to hatch when about five days old. The larva, half a day old, had a length of 3·99 mm., or a little less than $\frac{1}{6}$ inch. The mouth was formed, the pigment extremely faint and without special arrangement. It was absent from the fin-membrane, and there was no black pigment, only the yellow.

An older stage is figured by Holt. It was 4·65 mm. long, less than $\frac{1}{5}$ inch. The yolk was reduced to about half its bulk at the time of hatching, and the lower jaw was more developed. But the most striking change was in the pigment, the yellow having darkened to a chrome tint, and black specks having appeared. The pigment, moreover, now formed three distinct bands across the tail, one behind the other, as in the lemon dab and witch, but the bands did not extend on to the marginal fin-membrane.

Of the transformation stages we know nothing with certainty at present, for among the minute specimens of flat fishes collected at sea, this species has not been identified, at least not to the present writer's satisfaction. But very small specimens in the perfect or fully transformed condition were obtained in the course of the Irish Survey. Several were captured in the shrimp trawl in August 1890, at the depth of 80 fathoms, off the Skelligs. These ranged in length from $1\frac{1}{12}$ to $1\frac{2}{5}$ inches. On the following day more were taken at 52 to 62 fathoms in the same neighbourhood; these were from $1\frac{2}{5}$ to $1\frac{4}{5}$ inches. The smallest of these specimens is represented in Fig. 113. It will be seen that in this stage the transformation is very nearly complete, but the left eye still projects somewhat beyond the edge of the head. The three bands across the tail in the larva are still indicated by black patches opposite to each other near the margins of the upper or right side. The large size of the eyes, larger in proportion to the head than in the adult fish, is a characteristic feature. The number of fin-rays agrees with that of the full-grown fish. The large size of the mouth is another important point in the recognition of these small specimens. There can be no doubt, I think, that these fish were derived from the spawning of the preceding spring, and were therefore from three to five months old. I is evident, therefore, that the young of the long

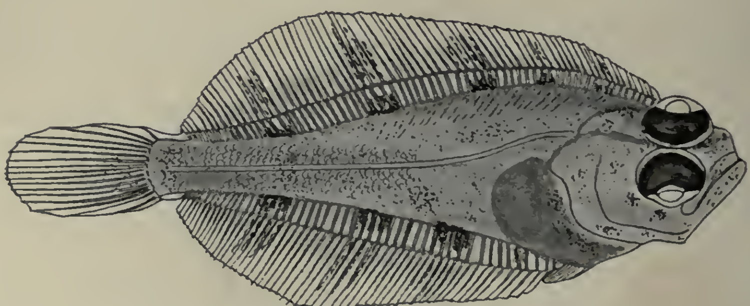

FIG. 113.—Young Long Rough Dab, $1\frac{2}{5}$ inches long; after Holt.

rough dab in their first year do not seek the shore and the shallows like the plaice and sole, but are found in deeper water like the lemon dab and witch. A few specimens taken with those just considered were about $3\frac{4}{5}$ inches long, and were doubtless in their second year. One specimen taken off the Aran Islands at 30 fathoms, in April, 1891, was $3\frac{1}{5}$ inches long, and must be considered to have been one year old.

During the Irish Survey larger specimens, 6 inches and upwards in length, were taken chiefly between 20 and 40 fathoms, so that it appears that the younger stages of life are passed by the long rough dab in deeper water than the older, the fish approaching nearer to the coast as it grows larger.

The Sole (*Solea vulgaris*).

Distinguishing Characters.—The chief peculiarities of the sole and other kinds resembling it are the narrow oval shape of the body, presenting everywhere a regular curved outline, and the character of the head. The mouth is not at the end of the snout, but behind it, and the jaws are curved, not straight. The outline of the snout is semicircular, and the dorsal fin commences on it in front of the eyes. The eyes are small. No bones are visible on the head, the scaly skin extending over all parts of it equally. On the lower side of the head there are no scales, but a number of short soft processes. The marginal fins extend to the base of the tail fin, but are not joined on to it.

The common sole is distinguished from others by the following points: pectoral fins on both sides of considerable size; that of the upper side with a black spot at its outer end; nostrils on the two sides similar; fin-rays, dorsal 73 to 90, ventral 61 to 74. Colour, brown or greenish-brown, with rows of darker blotches along the centre of the upper side, and along the bases of the fins. The usual length is 12 to 18 inches, but specimens have been recorded up to 26 inches long, and 11½ inches broad.

Habitat.—From the Mediterranean to the coast of Denmark and the Firth of Forth, north of which latitude it is rare. It is fairly abundant round the coasts of Ireland and in the Irish Sea. In the Bristol Channel and the English Channel, and also in the North Sea, it is taken in large numbers by the beam trawl.

The sole is distinctly a shoal water fish. In the Irish Survey the greatest number were taken between 5 and 30 fathoms, while a few were taken at greater depths up to 53 fathoms, and in less up to 5. The most productive sole grounds in the North Sea and English Channel are from 5 to 40 fathoms in depth.

Food.—The stomachs and intestines of soles examined from December to March at Plymouth were for the most part empty, probably because the spawning season was approaching. Thirty-six were found containing remains of food, and in eighteen these consisted of marine worms. Small fragments of the shells of bivalves were present in many, but these seemed in most cases to have been attached to the tubes of tube-building worms, although small bivalves were sometimes found in the entire condition. The throat teeth of the sole are pointed and slender, and cannot serve for crushing shells as do those of the plaice. Twenty-five per cent. of the stomachs contained echinoderms, mostly sand-stars. Crustacea were only found in 11 per cent. On the west coast of Ireland the order of importance of the different kinds of food was found to be the same: worms were most frequent, then sand-stars or other echinoderms, then molluscs, then crustaceans, and lastly fish in a few cases. The echinoderms were mostly brittle-stars or sand-stars, among the molluscs were small specimens of the razor shell, the crustaceans were usually small sand-hoppers or shrimps, the fish small sand-eels.

In the aquarium the sole will eat marine worms, shrimps, and pieces of fish or molluscs such as queens (*Pecten*) or mussels: but it prefers worms. When searching for food, whose presence it recognises by the smell, it glides gently about over the sand tapping with the lower side of its head in order to feel with the sensitive filaments there. But it soon gets accustomed to expect the food thrown into the tank, and often swims up from the bottom to seize it, although it is not very expert in doing this. Agitation of a handkerchief in front of the glass will cause the soles to collect to the front in expectation of food. The sole is one of the flat-fishes most addicted to burying themselves in the sand or gravel, leaving only their eyes exposed.

It is much more active by night than by day. This is proved not only by the unanimous testimony of fishermen that more soles are to be caught by trawling at night than by day, but by observation in the aquarium. On a visit after dark the soles are always found to be out of the sand, moving with some activity and searching for food, and when a light is directed upon them they soon bury themselves. As the sole trusts chiefly to the senses of smell and touch to find its prey, it can obtain food without difficulty in the dark, and seems in the natural state to use its eyes but little in hunting, a fact which is in agreement with the small size and slight mobility of those organs.

It is possible to capture soles by hook and line, but this method appears nowhere to be employed by professional fishermen except at Scarborough. A few men at that port set ground lines for soles in a little bay called Cloughton Wyke north of the town. The hooks are very small, and the bait used is lug worms. The fishing is carried on only in summer, the boats used being open cobles. Along the Yorkshire coast a rocky bottom extends out from the shore seawards for some distance, and only beyond it is sandy ground found in most places, but at Cloughton a narrow strip of sand runs almost to the head of the Wyke, and the soles are attracted to this spot by the large number of marine worms to be obtained there.

Breeding.—The proportions of the sexes in number and size have not been so carefully ascertained as in the case of other species, but there is no doubt that the females are both more numerous and larger than the males. In the Irish Survey, of 414 specimens examined, 245 were females, 169 males, or 144 females to 100 males. The smallest mature female was 2 inches longer than the smallest mature male. The very small size of the male sexual organs has already been mentioned in Part I.

Off the coast of Devon and Cornwall the spawning season extends from the middle of February to the middle of May. On the west coast of Ireland ripe females were taken in March, April, May, and June, but principally in March and April. In the North Sea spawning was observed from the end of April to the end of July. A sole of one pound weight has been calculated to contain 134,000 eggs.

Spawning takes place in the deeper water: on the south-west coast of England, outside the Eddystone, south of the Wolf rock, off the north coast of Cornwall, and in Mount's Bay, at from 20 to 40 fathoms. In the bays and inlets of the west coast of Ireland ripe females were taken between 5 and 15 fathoms, and also between 22 and 53 fathoms.

The egg of the sole when fertilised is buoyant, and floats in sea water: it is 1·47 to 1·51 mm. in diameter ($\frac{5}{100}$ to $\frac{6}{100}$ inch, or $\frac{1}{20}$ inch). It is easily distinguished from the eggs of other fishes in British seas by the facts that the outer layer of the yolk is divided into separate segments, and that there are an immense number of minute oil globules arranged in irregular patches at the surface of the yolk (Fig. 114).

The larva hatched out on the tenth day at a temperature of 48° to 50°. The larva resembles that of other flat fishes, except in the peculiarities of the yolk; it is 3·5 to 3·7 mm. long ($\frac{2}{16}$ to $\frac{3}{16}$ inch); the coloured pigment is orange-yellow by reflected light, pale when the light comes through it: the pigment is rather abundant and occurs on the body, yolk-sac, and fin-membrane, without any particular pattern (Fig. 115).

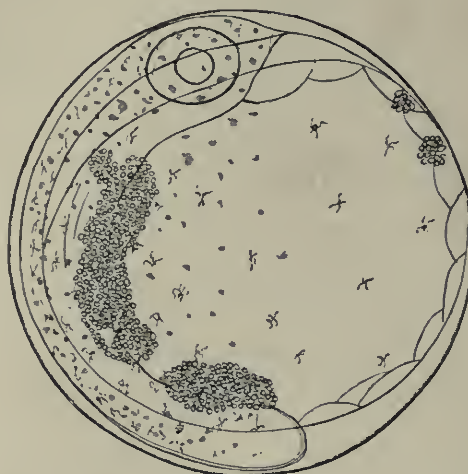

FIG. 114.—Egg of Common Sole, alive and magnified.

The larva six days old had its mouth fully formed, and the yolk reduced to half its bulk. Even at this early age the pro-

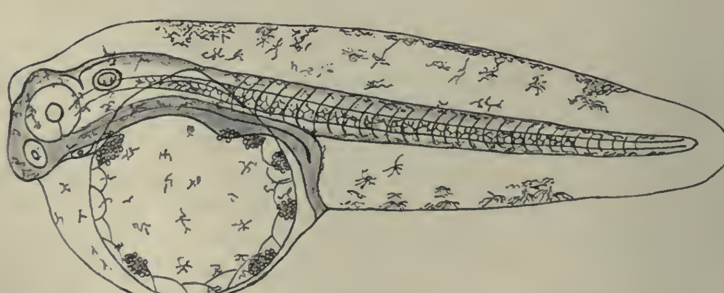

FIG. 115.—Larva of Common Sole, newly hatched, alive and magnified.

jection of the snout above the mouth is noticeable, and another peculiarity is the elevation of the fin-membrane above and just behind the head. The black pigment forms a row of spots on the dorsal fin-membrane. Fig. 116 shows the appearance of the larva at this stage.

A stage in the transformation of the sole was seen in a specimen taken with a hand-net amongst the seaweed on Plymouth

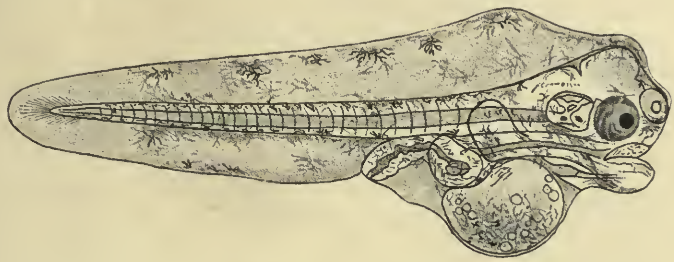

FIG. 116.—Larva of Common Sole, six days old, alive and magnified.

Breakwater (Fig. 117). The left eye is still on its own side, but very near the edge of the head. The specimen was 11 mm. long ($\frac{44}{100}$ inch). It differs from the corresponding stage of the flounder by the great length of the dorsal and ventral fins, which behind reach to the base of the tail, and the dorsal in front is almost projecting over the rising left eye. The

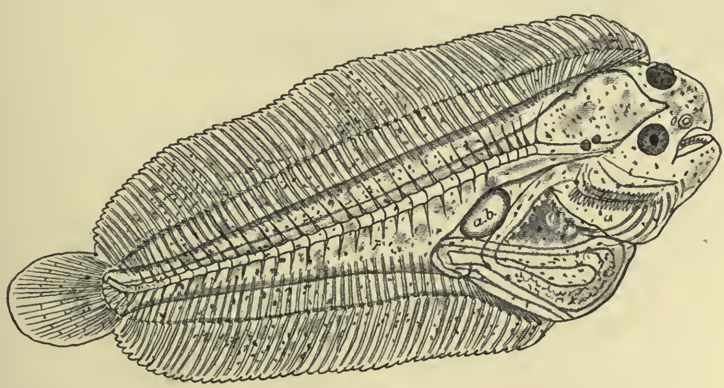

FIG. 117.—Transition stage of Common Sole, alive and magnified; *a. b.* air bladder.

fin-rays and skeleton are well developed. Other peculiarities are the breadth of the abdominal region, and the presence of a rather large air-bladder which is entirely wanting in the full-grown sole. The pigment forms obscurely-marked spots.

This is the only specimen of the sole in the period of transformation yet obtained in Britain ; it was taken on August 9th, and such stages must occur somewhere at an earlier date in the year. They have not been seen at the surface like the young turbot and brill, nor at the margin at low tide like the flounder, nor have been captured near the bottom like plaice and dabs. As they have an air-bladder it is probable that they swim near the surface, or far from the bottom.

The next stage of the sole which is known is that in which the transformation is just complete, and the little fish is very like the adult, but more transparent. This stage is represented by specimens 12 to 15 mm. long ($\frac{1}{2}\frac{2}{5}$ inch to $\frac{3}{5}$ inch) taken to the number of fifteen at one time from the end of April to the middle

FIG. 118.—Young Common Sole, just after its tranformation, alive and magnified.

of May in the tide-pools of Megavissey Harbour, in Cornwall. They had lost their air-bladder. Their ages may be reckoned at about two months (Fig. 118). They were very much scarcer than the flounders taken with them, and also somewhat older, that is to say more advanced in development. It is evident that the soles do not seek the marginal region at so early a stage as the flounder.

Young soles between the end of their transformation and one year of age have not yet been frequently observed in large numbers. At Plymouth and along the Cornish coast I searched for them from time to time in the course of several seasons without success. A few specimens less than 2 inches long were trawled by Mr. Holt at the mouth of the Humber, in October and November, and these in all probability were derived from the preceding spawning season in the same year, and were therefore about five or six months old. In September, 1895, I saw some hundreds of small soles 2 to 2½ inches long brought up in the trawl of a professional shrimper working on the Newcome Sand, off Lowestoft. The depth was 1½ to 2 or 3 fathoms, and the number of these young soles at each haul varied from 20 to 100. The other contents of the net consisted of shrimps, a few larger soles 6 to 9 inches long, a few plaice about the same size, and a considerable number of small whiting 3 to 12 inches long. Plaice and dabs as small as the small soles were very scarce. Besides the fish there were quantities of zoophytes and various worthless fish, namely, weevers, gobies, pipe-fishes, &c. There were also some star-fishes, swimming-crabs, shore-crabs, sand-hoppers, and bivalve shell-fish.

In tracing the history of young soles it is very important to distinguish them accurately from specimens of the solenette, which are about the same size, and at first sight extremely similar in appearance. In fact both fishermen and fish merchants constantly mistake the solenettes, which are frequently taken by the large beam trawl on many of the North Sea fishing grounds, for young soles. In the long course of my experience I have met with only one skipper who held the opinion that the solenette was a distinct kind of fish from the sole, and he was not aware of the exact points of difference between them. The solenette can always be distinguished by the absence of the breast-fin, and the black lines on the marginal fins. The young of the common and valuable sole has only been taken hitherto in shallow water near shore, while the solenette is often found in the crevices of the ground rope on the grounds of the southern and eastern parts of the North Sea, many miles from land, where the depth is less or not much more than 20 fathoms.

The smallest soles taken in the shove-net at the mouth of the Humber in April, were 2⅝ inch to 3⅝ inch long, and occurred only in small numbers, four in one haul. These were evidently the produce of the preceding season, and might be from 8 to 12 months old. Five taken in May were 2½ to 4⅝ inches long, fourteen in June 2½ to 4$\frac{7}{16}$ inches, five in July 3⅜ to 7½ inches long. We have various reliable descriptions of the numbers and kinds of small fish taken in shrimp-trawling. At Plymouth I have never seen large numbers of year-old soles taken in the small beam trawl used for shrimps. Dr. Fulton found that in the Solway Firth in June only eleven soles, $2\frac{3}{4}$ to 6 inches long, were taken in five hauls, the depth of water being 3 to 15 feet. On the Lancashire coast a great deal of inshore fishing goes on, including shrimp trawling, and yearling soles, 3 to 6 inches in length, are taken in considerable numbers. The proportion however in number of these to small plaice is not great, the lowest was 4 soles to 900 plaice, and the highest 136 soles to 520 plaice. The fishing is carried on chiefly in the summer months, at depths from 3 to 10 fathoms. That yearling soles do occur sometimes in large shoals, in inshore waters, is proved by an observation made by myself, on the Essex coast. There on board a shrimp trawler, fishing in the Wallet, from Colne Bar up to Clacton, in the beginning of June, I saw very large numbers of small flat fishes brought up with the shrimps, and although plaice and dabs were most abundant, there were many hundreds of small soles 3 to 5 inches long, and also many lemon dabs. There can be no doubt that these soles were the produce of the preceding season. As all the flat fishes were culled out by hand and thrown overboard, there was no great destruction of the valuable soles, which are not injured by such a course of treatment, provided they are not kept on the deck of the boat too long.

A few soles may possibly reach a length of 8 inches, when one year old, but it is pretty certain that the great majority at that age measure between 3 and 6 inches. It appears from the evidence summarised above, that soles in the first year of life are confined to inshore waters, to depths less than 10 fathoms.

Immature soles above 6 inches in length, do not seem to frequent different grounds from those on which the full-grown fish are found. Both the immature and the mature after spawning are found, especially in summer, on inshore grounds, and in estuaries up to a considerable distance from the sea. Thus four were taken in July at Malpas in the Fal estuary more than ten miles from the sea. In the Humber in May small boats get as many as thirty from 7 to $10\frac{1}{2}$ inches long, in a night's fishing, and larger spent fish are taken there in July, August, and September.

Size at which Maturity is reached.—There seems to be no great difference between the size at which soles begin to breed in the

North Sea and off the coasts of Devon and Cornwall. The smallest mature females observed at Grimsby were 10 inches long, at Plymouth 12 inches, the largest immature 12 inches at Grimsby, 13 inches at Plymouth. The smallest mature males were 8 inches long at Grimsby, 9 at Plymouth. Considering the difficulty of the question, it cannot be said that the largest size of immature males has been determined with certainty.

Migrations and Habits.—It is questionable whether any soles remain in estuaries, or in very shoal water in the coldest time of the year. A few were taken in the Humber below Grimsby, up to November 17th, but they are much more abundant there from May to September. Spawning fish are not found, generally speaking, at less than ten fathoms, and are usually found beyond twenty fathoms. As far as the evidence goes, it may be concluded that there is a general movement of all soles in very cold seasons to deeper water, and of immature and spent, that is feeding-fish, to the shallower waters in the warmer periods of the year.

The Sand Sole, or French Sole (*Solea lascaris*).

Distinguishing Characters.—Both pectorals well developed as in the common sole, but the front nostril on the blind side much enlarged, fringed on the outer edge and with folds on the inner. The fin-rays are usually somewhat fewer in number than in the common sole, dorsal 79 to 89, ventral 67 to 71. The scales are larger. The dorsal commences further forwards, on the extremity of the snout. The colour is brighter, yellowish, with small black spots without definite arrangement, and gold specks. In size it is somewhat smaller than the common sole, usually 8 to 12 inches, and not known beyond 14 inches.

Names.—This species is sometimes called the lemon sole, but it is quite different from the lemon dab, which is commonly called lemon sole.

Habitat.—From the shores of England and Ireland to the Mediterranean, and probably farther south. It is scarce in British waters, commoner in the Mediterranean. Has been taken as far north as Banffshire, occasionally taken in the southern part of the North Sea, English Channel, and Irish

Sea. Three specimens were taken in the Irish Survey, in shallow water, 1½ to 9 fathoms, in April. Three specimens under 8 inches in length were taken in Whitsand Bay, near Plymouth, in June.

The eggs and young have not been traced.

The Solenette, or Little Sole (*Solea lutea*).

Distinguishing Characters.—The pectoral or breast fins, and the pelvic or throat fins very small, represented only by slight rudiments. Dorsal fin commences on the extremity of the snout, contains 65 to 73 fin-rays; the ventral fin contains 50 to 63; these numbers are fewer than in the common sole. The scales are larger than in the latter. The colour is yellowish-brown, with dark spots arranged as in the common sole, but there are black lines at regular intervals on the marginal fins, each corresponding to a fin-ray. *Does not grow to more than* 5 *inches in length.*

Habitat.—Extends from the Mediterranean to the north of Scotland. It is fairly common all round the British and Irish coasts, but usually confounded with the young of the common sole, although it can be distinguished with complete certainty at any size. Off Plymouth it has been taken at depths up to 20 fathoms, on the west of Ireland up to 38, in the North Sea it is common on various grounds; for instance, the eastern grounds and the Brown Ridges, up to about 20 fathoms. Specimens are very often found in the crevices of the ground rope of the trawl. At a length of 2 inches to 3½ inches it is common in Cawsand Bay, Plymouth Sound, where adults 4 to 5 inches long are also taken. It has not been found in the Humber estuary, probably because it avoids brackish water.

Breeding.—The females are larger and more numerous than the males, the former becoming mature at 3½ inches, the latter at 3 inches or less.

The egg has not been fertilised from the fish, but buoyant eggs obtained by the tow-net in the Irish Survey, and resembling those of the thickback, only much smaller, probably belonged to this species. The larva when first hatched was just over $\frac{2}{25}$ inch (2·02 mm.).

The Thickback (*Solea variegata*).

Distinguishing Characters.—Pectoral fins very small, rudimentary. Mouth straighter and nearer the snout than in the other species. Marginal fins do not reach the root of the tail. Fin-rays about the same number as in the solenette. Colour, brownish-red with five dark bands across the body, the ends of which bands on the fins are black. Grows to 8½ inches in length.

Habitat.—From the Mediterranean to the British Islands. It is common off the coasts of Devon and Cornwall. Only one

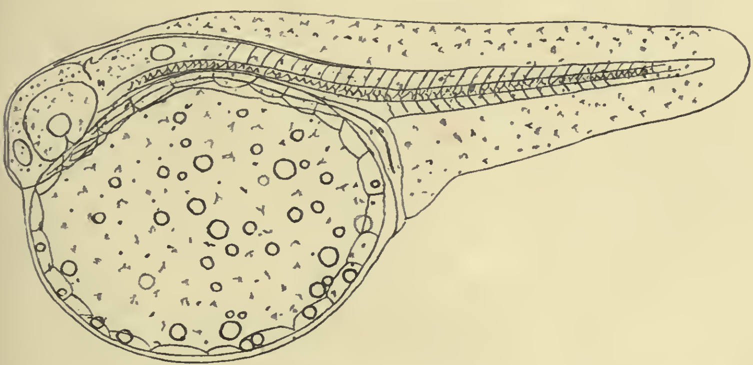

FIG. 119.—Newly-hatched larva of the Thickback, alive and magnified.

was taken in the Irish Survey, but it has been obtained on the west of Scotland. It is not found in the North Sea or on the east coast of Scotland usually, although said to have been taken off Banffshire.

It is a deep water species, at least in our latitudes, not having been taken in less than 20 fathoms, and it was trawled off the south-west of Ireland at 150 fathoms. Off Plymouth it is abundant to the south of the Eddystone, in from 30 to 40 fathoms.

The females are more numerous and larger than the males; in one lot there were 179 females to 34 males, or 526 of the former to 100 of the latter.

They were spawning freely south of the Eddystone in April.

The eggs have been taken from the fish in the ripe condition, and also obtained in abundance from the sea. They differ from those of the sole chiefly in the fact that the oil globules are larger and scattered singly and separately over the surface of the yolk. The egg is 1·36 mm. in diameter (a little more than $\frac{1}{20}$ inch). The larva when first hatched (Fig. 119) resembles that of the sole, but the pigment is lighter; the larva is 2·42 mm. in length (not quite $\frac{1}{10}$ inch), considerably smaller than that of the sole.

Intermediate stages have not been seen. The youngest fully developed specimen obtained was 1·8 inch long, taken, in July, two miles north of the Eddystone. This specimen was possibly only three months old, but more probably a year.

The Turbot (*Rhombus maximus*).

Distinguishing Characters.—Eyes and colour on left side, body very broad, mouth large, teeth and jaws on the two sides equal. Distinguished from the brill by the greater breadth of the body in proportion to the length, the absence of scales, and the presence of scattered, large, bony, blunt tubercles. The fin-rays are few in number, dorsal 61 to 72, ventral 45 to 56. Colour in life speckled, light or dark according to the bottom it lies on: after death a dark brown somewhat mottled.

Size.—The average length of the mature males, according to Dr. Fulton, is 17·2 inches, the largest 24 inches; of the mature females the average 20·3, the largest 28 inches. A male 26 inches long, weighing 14 lbs., was taken during the Irish Survey. Buckland records a turbot which weighed 32 lbs.

Habitat.—A rather southern fish, extending throughout the Mediterranean and Black Sea, and northward to the latitude of Denmark and the southern part of Scotland, north of which it is rare. It does not exist on the American side of the Atlantic. It is rare on the coasts of the Orkneys and Shetlands, absent from Iceland. It was taken in considerable numbers during the Irish Survey on the west coast of Ireland, and occurs also on the north-east and south coasts. In the English Channel it forms an important part of the produce of the trawl fishery.

It is a shallow water fish. None were taken on the west coast of Ireland at depths beyond 40 fathoms, and even the larger specimens are often taken in 3 to 10 fathoms, a short distance from the beach. It does not however ascend estuaries, in the adult state, though a few young are taken in the lower parts by shrimpers.

Food.—The turbot, especially when of considerable size, feeds almost entirely on other fish. It is a predaceous creature, whose powers of concealment by means of covering itself with sand, and assimilating its colour to that of the surrounding ground, enable it to lie in wait until some fish is near enough, and then suddenly to rise from the ground and seize it. On the west of Ireland the principal fish found in turbots' stomachs from May to August were sprats and sand-eels (*Ammodytes*). In one specimen, 17½ inches long, more than sixty sand-eels were found. A dab, a sole, and a pout (*Gadus Esmarkii*), and a dragonet were also found each once. Bivalve molluscs and worms were found in one fish each.

On the trawling grounds of the south-west of England I have found in turbots' stomachs, the boar fish, commonly called cuckoo by the fishermen, pilchards, whiting, young sea bream (*Pagellus centrodontus*), pout (*Gadus luscus*), and never found anything besides fish.

Breeding.—According to Dr. Fulton the female turbot is more numerous than the male, in the proportion of 197 to 100, and larger on the average in the proportion of 118 to 100 by length. The total number of eggs in the ovaries varied from 5,612,000 in a fish of 18 lbs. weight, to 10,114,000 in a fish weighing 21 lbs. Buckland calculated the number of eggs in a turbot weighing 23 lbs. as 14,311,000.

. According to Dr. Fulton's results, turbot spawn on the east coast of Scotland in April, May, June, and July. Mr. Holt's observations, at Grimsby, gave the same result, but extended the period for a small proportion of fish to August and the commencement of September. The spawning period is thus prolonged. On the west coast of Ireland the observations were not extensive, but spawning was taking place in April, May, and June.

The eggs of the turbot when alive and fertilised measure 1·01 mm. in diameter ($\frac{1}{25}$ inch), almost exactly the same size as those of the flounder. But they differ from these in having a single oil globule in the yolk, and this has a pale ochre colour. The egg-membrane is close to the yolk, as in most buoyant eggs. It was found that a few days after fertilisation the eggs sank to the bottom of the jar, although they were studied on board a fishing vessel in the open North Sea, so that the later development takes place nearer the bottom than the surface of the sea.

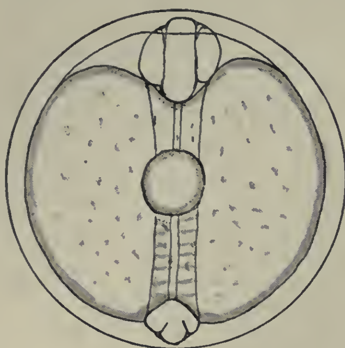

FIG. 120.—Egg of the Turbot, alive and magnified; after McIntosh.

The larvæ were hatched out seven to nine days after fertilisation. They were small, measuring only 2·14 mm. in length (a little more than $\frac{1}{12}$ inch), and the tail portion is a good deal shorter than the yolk-sac (Fig. 121). Neither mouth nor anus is formed, the fin-membrane is narrow, and generally the larva is less developed than that of the plaice or flounder when first hatched. The coloured pigment specks by reflected light are a red-orange, and when seen by the

FIG. 121.—Larva of Turbot newly-hatched; after Holt.

light passing through are much the same but more inclined to crimson. None of the larvæ lived more than a few days after hatching, but a good series of older stages was obtained by Mr. Holt from the North Sea, by means of the tow-net worked at the surface, in July. These specimens range in length from 3·42 mm. to 16·25 mm. (a little more than $\frac{12}{100}$ to $\frac{65}{100}$ inch).

The smallest of these larvæ (Fig. 122) is still equal-sided: the

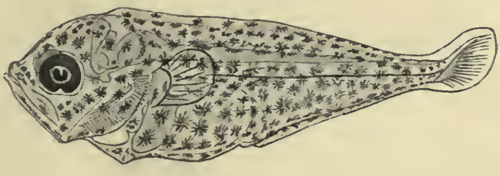

FIG. 122.—Larva of Turbot, a little more than $\frac{1}{8}$ inch long, from a preserved specimen; after Holt.

head is relatively large, the tail fin is forming, but the marginal fins are very narrow and without fin-rays. The jaws are fully formed, and the mouth is very wide: the hinder end of the body narrows rapidly. All the stages possess an air-bladder. At 5·42

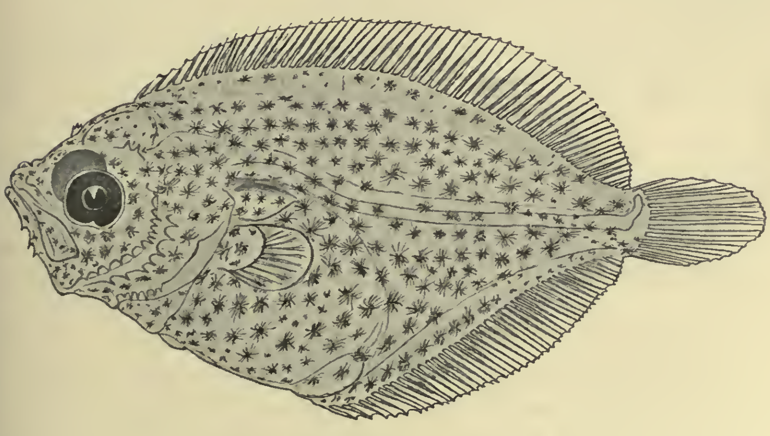

FIG. 123.—Larva of Turbot, a little more than $\frac{1}{5}$ inch long, with spines on the heap, from a preserved specimen; after Holt.

mm. (a little more than $\frac{1}{5}$ inch), the development is much more advanced (Fig. 123). The body has increased greatly in breadth, the tail-fin and marginal fins are well developed and provided with complete bony fin-rays. The eyes however are still nearly opposite to one another, the right being only a little higher than the left.

The pigment in these specimens is dark, the black specks are very abundant and evenly distributed, so that no spots or bands are visible; this distinguishes the turbot from the corresponding stages of the brill. Another remarkable peculiarity is that in the stages from that of 5·42 mm. in length to that in which the transformation is nearly complete the head is provided with a large number of spines, no trace of which remains in the full-grown fish. There is a row of these spines above the eye, a few at the hinder part of the lower jaw, and two strong rows on the gill-cover. The spines are most developed in specimens 10 or 11 mm. long ($\frac{2}{5}$ inch), and after that gradually disappear. At 13·5 mm. in length (just over $\frac{1}{2}$ inch) the right eye is just beginning to show beyond the edge of the head when the specimen is placed on its right side. In the largest specimen, 16 mm. long, ($\frac{64}{100}$ inch) half of the right eye is visible from the left side.

These specimens were captured off the Horn Reef light vessel, near the coast of Denmark, on the Great Fisher Bank, and off the north-west corner of the Dogger. It is a curious fact that while they were brought to Grimsby from distances between 60 and 220 miles in the North Sea, numbers of specimens in the older stages come, of their own accord, almost to the doors of the Plymouth Laboratory. They are brought in with the flood tide to Sutton Pool, and, swimming as they do at the very surface of the water, are dipped up by boys in rusty tins and brought to the Laboratory for sale. The sizes of such specimens are commonly from 15 to 25 mm. ($\frac{6}{10}$ to 1 inch), but recently a series of the younger stages described by Mr. Holt were obtained in the same manner. Fig. 124 represents a specimen $\frac{4}{5}$ inch long. There are several interesting and remarkable features about these young forms. The transition stages of other flat-fishes have been obtained near the bottom; those of the flounder, plaice, and dab, have no air-bladder, and when their habits are noticed it is seen that they swim up from the bottom by active exertion of the fins and fall when not moving. The sole has an air-bladder in the transformation period, but has not been taken at the surface in the open water. But the young turbot float, or soar, in the water with no exertion at all, using their fins gently now and then to move deliberately and rather slowly in one direction or another. They can also in a tank lie at the bottom, and although found at the surface, seem to be able to sink or rise as they please. They are not easily alarmed, and when one tries to catch them, seldom attempt to escape, so that they can be dipped up with a small vessel or the hand with the greatest ease. Other flat-fishes in these stages are very transparent, and therefore not easy to see in the water, but the turbot and brill are opaque from a very early stage, from the very commencement of the development of the fin-rays and bones. The large size reached by these fish before the trans-

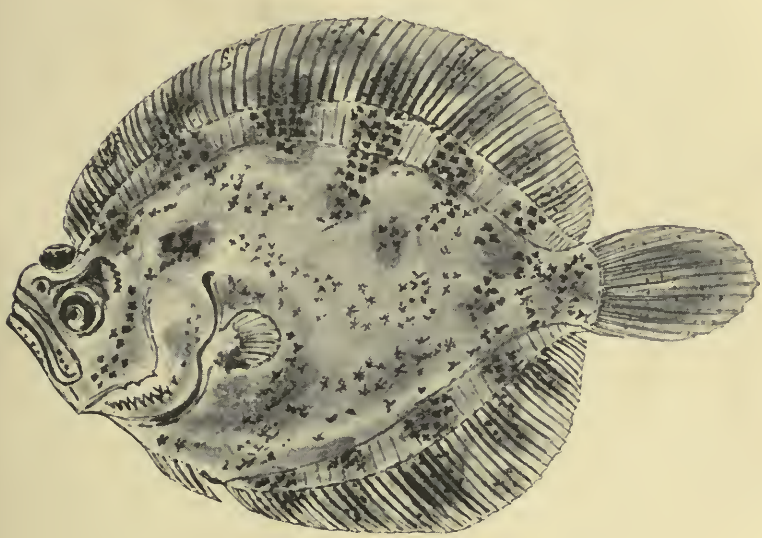

Fig. 124.—Transition stage of Turbot, $\frac{4}{5}$ inch long, from a preserved specimen; after C. G. Joh. Petersen.

formation is complete is also remarkable, the turbot being sometimes over an inch long before they remain on the bottom and acquire the complete form and habits of the adult. It must not be supposed that these fish in the process of transformation swim upright like a fish whose two sides are alike. So long as they are equal-sided, that is up to a length of about $\frac{1}{4}$ inch, while the eyes are opposite to one another they do swim in that position, but as the right eye begins to rotate the body is held in a correspondingly slanting position, and when the eye reaches the edge or upper (left) side of the head they swim with the body horizontal, in the same position, or nearly, as when lying on the bottom.

The advantage of this power and habit of swimming at the surface is not difficult to discover. Even at these early stages the turbot and brill are rapacious and feed on other fishes smaller than themselves. They might capture such prey when lying like the adult at the bottom, but in summer time the young of other kinds of fishes are much more plentiful in the open water and near the surface than at the bottom. In the aquarium at Plymouth the young turbot have been fed on pieces of dead fish, but both they and the brill much prefer living prey, and when kept with other young fish, such as flounders, speedily devour them, or choke themselves in the attempt.

After completing their transformation, losing the air-bladder, and assuming the habits of the adult fish, young turbot have only been found in very shallow water, near the margin of the sea. At St. Andrews they have been taken with a seine net in September and October, at a length of 2 inches. These are doubtless the young hatched the previous summer. At Cleethorpes, from April to June, specimens from 3 inches to $4\frac{1}{8}$ inches long are taken in small numbers in the shove-nets of the shrimpers. These are only the smallest of the brood of the preceding year, the majority of turbot a year old being larger. The limiting sizes of mature and immature turbot observed at Grimsby were for females 14 inches and 19 inches, for males 12 inches and 15 inches. As in other cases, these limits give the sizes attained by some specimens at two years of age, while the size of the smallest mature male may be taken as the greatest size reached by the female at the end of the first year. On the eastern grounds of the North Sea small turbot are taken in considerable numbers, together usually with a proportion of adults. The total catch on one voyage of a steam trawler on these grounds in June was 140 specimens, ranging in size from 11 to 15 inches. Judging from the size, some of these may have been mature. In a single haul of the trawl at 10 to 12 fathoms, about twenty miles from the Amrum Light, north of Heligoland, also in June, there were taken two mature female turbots $14\frac{3}{4}$ inches and 24 inches long, nine immature females $13\frac{1}{2}$ inches to $15\frac{1}{2}$ inches, and twelve mature males 13 inches to 16 inches. There can be no doubt that the year-old turbot, mostly from

4 to 8 or 9 inches long, live chiefly in the shallower water close to the shore, and that the sample just mentioned included fish of two years of age and upwards. It will be noticed that mature turbot, some even of large size, are by no means entirely absent from the eastern grounds at twelve fathoms.

The Brill (*Rhombus lævis*).

Distinguishing Characters.—Resembles the turbot in shape of body, thickness and firmness of flesh, toughness and deep colour of skin ; but it is narrower in proportion to its length and more regularly oval. It has small smooth (cycloid) scales all over both sides, but they project slightly from the skin ; no tubercles. The fin-rays are more numerous than in the turbot, dorsal 76–85, ventral 53–63. The dorsal commences in front of the upper eye, and its first ray is much branched. Colour in the dead fish dark and uniform ; in life variable and speckled : lower side white.

Size.—The largest female recorded by Dr. Fulton was 26 inches long, largest male 23 inches. They are commonly seen in the market from 13 to 20 inches long.

Habitat.—There seems to be no difference in this respect between the brill and the turbot. The former is found throughout the Mediterranean, and all round the British Isles, becoming rare in the Orkneys and Shetlands. Like the turbot it is rarely taken at depths greater than 40 fathoms, and occurs on sandy, gravelly, or muddy ground. In the North Sea it is taken on the Lincolnshire coast, the neighbourhood of the Dogger Bank and Silver Pit, and off the Dutch and German coasts ; but northwards about the Great Fisher Bank, at depths over 40 fathoms, neither turbot nor brill are often taken.

Mature brill, though often to be found in shallow bays, do not usually enter estuaries, but the younger stages are often found in the more seaward parts of the latter.

Food.—As in the case of the turbot the food consists almost entirely of other fishes. Ninety-four specimens were examined during the Irish Survey, and in only three cases was anything else observed ; in two of these cases the food was squid, in the third a shrimp. The fish found was in nearly all cases sand-eels, occasionally sprats were present, and a dragonet and solenette occurred each once. On the south coast, judging from observations made in the Plymouth Laboratory in February, the smaller members of the cod tribe are the chief victims, namely the poor cod and pout, or bib (*Gadus minutus* and *G. luscus*).

Breeding—Dr. Fulton found that the females were more numerous than the males in the proportion of 145 to 100, and larger in the proportion of 123 to 100. The total number of ova in one specimen weighing 5½ lbs. was found on calculation to be 825,000. Spawning was found to be taking place off the east coast of Scotland in April, May and June, and a few were stated to be ripe in March. According to Mr. Holt's observations at Grimsby, ripe fish were first seen in the latter part of April, were abundant in May and June, and none were seen after the end of July. In the neighbourhood of Plymouth spawning takes place chiefly in April, May, and June; and during the same months on the west of Ireland.

The Eggs and their Development.—The eggs of the brill were procured from ripe fish both on the east coast of Scotland and on the west of Ireland, but they were hybridised in fertilisation, in one case the milt of a turbot being used, in the other that of a dab. In the former case the eggs developed healthily and hatched; in the latter, as might be expected, they died before hatching. In 1892, however, eggs were obtained at St. Andrews fertilised from the male of the same species. They are buoyant eggs, with a single oil globule, like those of the turbot, but larger, measuring 1·33 mm. in diameter. The oil globules are slightly coloured, giving a number of living eggs together a pale inky tint. The embryo in the egg after some days' development is remarkable for the abundance of pigment on the surface of the yolk sac, and on the head and body: there are numerous black star-shaped specks, and spots of yellow colour.

Unfortunately the early larval stages are not satisfactorily known. We have a figure by Raffaele[1] of a larva hatched at Naples from eggs taken from the sea and identified as those of the brill. The identification is doubtless correct, and the larva is characterised by the abundant pigment mentioned already, now of a slightly darker chrome tint. It forms one distinct band across the tail as in the larva of the flounder. The fin-membrane

[1] *Mitt. Zool. Station, Neapel* 8 Bd. 1 Heft, 1888.

extends on the back to the front of the head. McIntosh[1] has figured a larva from the eggs fertilised with turbot milt, which is closely similar, except that the oil globule is farther back in the yolk.

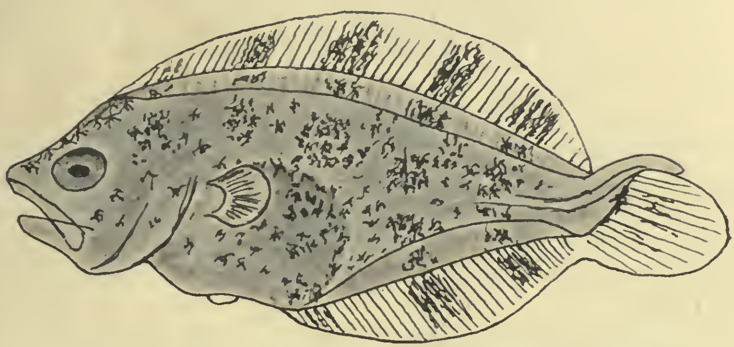

FIG. 125.—Larva of Brill with two sides still similar; after Raffaele.

After this stage we have no observations until we reach stages in which the fin-rays are formed, and the mouth and jaws well developed. The earliest of these figured by Raffaele (Fig. 125) is

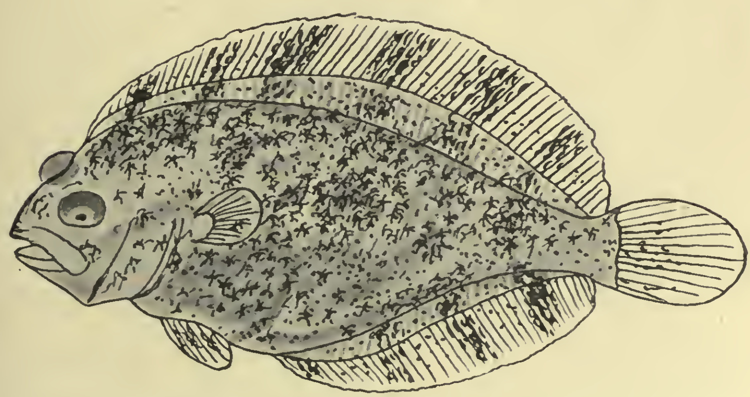

FIG. 126.—Larva of Brill with right eye nearly at the top of the head; after Raffaele.

$\frac{3}{8}$ inch long; it is still equal-sided. The pigment is abundant, and forms distinct bands across the sides, five in number. The next stage (Fig. 126) with the right eye nearly at the top of the head

[1] *Ninth Report Scottish Fishery Board.*

is $\frac{11}{16}$ inch long and shows six bands. It is distinguished from the turbot by these bands, by its narrower form, and by the greater number of fin-rays. In the oldest stage figured by Raffaele the transformation is practically finished, the two eyes are on the left side, and the bands are breaking up into spots. These specimens were obtained at the surface of the sea, in the Bay of Naples.

Like the young turbot, the brill in the stages just described are found with unfailing regularity and in considerable numbers every year at Plymouth, at the surface of the fishing harbour, Sutton Pool. They swim quite at the surface, having a large air-bladder which enables them to support themselves in the water without exertion, and they are carried by the flood-tide into the harbour.

A number of these young brill were reared in the aquarium at Plymouth. One of them was nearly 3½ inches long in October when about six months old, and four others were from 3 to nearly 4 inches in the same month. Two were kept till the following April, and were no larger than those which were killed in October, namely, between 3 and 4 inches in length. That these results are not altogether unnatural is shown by their agreement with the conclusions to be drawn from the size of the young brill taken in the shove-nets at Cleethorpes from April to July; ten of these varied in length from 3 to 5½ inches, and must necessarily have been hatched the preceding season.

The brill reaches maturity probably at a slightly smaller size than the turbot; the smallest ripe male in the North Sea was 10 inches long: of females the smallest mature was 13 inches, the largest immature under 16 inches. As in the case of the turbot both mature and immature are taken at about 12 fathoms, to the north of Heligoland. The history of the young brill agrees closely with that of young turbot, the yearling fish being confined to the shallowest water near the shore, the older immature with some mature being found between 10 and 20 fathoms; beyond 20 fathoms usually only mature fish occur.

The Megrim (*Lepidorhombus megastoma*).

Distinguishing Characters.—This fish has a large mouth, large head and large eyes, and a rather narrow, thin, pale body. The teeth equally developed on the two sides, small, in two rows, also on vomer. The eyes are on the left side as in turbot and brill. The curve of the lateral line above the pectoral is somewhat oblong, not semicircular. The skin is thin, and the scales which are large and spinous (ctenoid), easily detached. The dorsal fin commences in front of the upper eye, but the first rays are not elongated or branched. The fin-rays are more numerous than in the brill, namely, dorsal 85–91, ventral 61–75. Colour, a pale brownish yellow without distinct markings. Flesh rather dry.

Size.—The largest recorded was 23½ inches long: the largest taken in the Irish Survey was 18 inches.

Names.—This fish is called by a different name at almost every fishing port. At Plymouth it is always known to the fishermen as the megrim, while the hawkers call it the lemon sole. In Cornwall it is known as the whiff. Couch describes it as the carter and the sail-fluke, supposing that there are two separate kinds. In Cornwall it is also called lantern-fish, from its transparency, as another species is called window-pane in America. In Dublin it is called white sole, ox sole, and lemon sole.

Habitat.—It is fairly abundant from the Bay of Biscay to the north coast of Norway. Doubtful whether it exists in the Mediterranean or whether its place there is taken by the allied species *L. boscii.* It occurs on the coast of Iceland. Not abundant in the North Sea.

This fish has a great range in depth. During the Irish Survey specimens of 12 inches in length and upwards were taken at various depths from 4 to 220 fathoms. They occurred in numbers at 20 to 25 fathoms, at 50 to 60 fathoms, and at 154 fathoms.

It is evident that this fish is fairly abundant off the S.W. of England, and on the western shores of Ireland and Scotland to the Orkneys, and again further north, and yet is comparatively rare in the North Sea and the Irish Sea. The probable explanation is that in these latitudes it properly belongs to ground beyond the 50 fathoms line, and only makes temporary migrations into shallower water. In the works of Day and Couch are quoted stories of its coming ashore in the Orkneys spontaneously, with its tail erected above the water to act as a sail; and the name sail-fluke is said to be derived from this peculiar habit. Whether there is any important fact concerning the habits of the fish at the base of these stories is uncertain, but at any rate no one would take them seriously without the evidence of some competent observer.

Food.—According to the observations made in the Irish Survey, the principal food, as in the case of the turbot and brill, is fish, namely, sprats, sand-eels, whiting, gobies, &c. Crustaceans, common shrimp and others, and squid, were found in one or two specimens.

Breeding.—Dr. Fulton found that the females were both larger and more numerous than the males, but as he only examined twenty-one specimens, too much importance must not be given to his figures. The proportions were in number 133 to 100, in length 131 to 100. On the west of Ireland the numbers found were: males 43, females 160, or 372 females to 100 males.

On the west of Ireland these fishes were spawning in March, April, and May. Spawning fish were only taken at 53, 154, and 200 fathoms, a fact which confirms the suggestion that the species belongs properly to the deep water. Numbers of specimens were taken in shallower water, but though some were mature none were ripe. The number of ova in a female 18 inches long, was found on calculation to be 440,000.

The eggs are like those of the turbot and brill, having a simple yolk with a single oil-globule. In size they most resemble those of the turbot, their breadth being 1·13 mm. ($\frac{45}{1000}$ inch). They have been examined both in the Irish Survey and at St. Andrews. Hatching took place on the sixth and seventh days after fertilisation. The larva was distinguished from those of most other flat-fishes by the almost entire absence of coloured pigment, the black specks being scattered equally over the head, body, and fin-membrane, but not on the yolk sac. The oil-globule is placed at the hinder end of the yolk, and the end of the intestine is slightly separated from the yolk sac. When the larvæ were four or five days old, the mouth became open and yellow pigment had appeared. The later larval stages have not been traced.

The next stage known is the youngest shown in small specimens trawled during the Irish Survey at 80 fathoms, off the Skelligs in August. The smallest of these was 19 mm. long ($\frac{76}{100}$ inch, or not quite $\frac{4}{5}$ in). Its transformation is nearly but not quite complete (Fig. 127). The right eye is on the left or upper side of the head, and the front part of the dorsal fin has grown forward to a point opposite the middle of that eye. The pigment has already disappeared from the blind side. The scales have not yet appeared.

Specimens 30 mm. long ($1\frac{1}{5}$ inches) are still more like the adult, the posterior part of the body having grown broader.

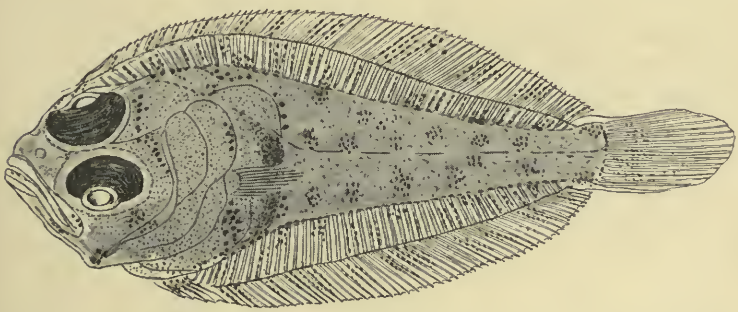

FIG. 127.—Young Megrim or Sail-fluke, not quite $\frac{4}{5}$ inch long. From a preserved specimen ; after Holt.

Scales are developed at the root of the tail, and extend forwards along the lateral line, but are absent elsewhere. In specimens 50 mm. long (2 inches) the scales are developed all over the skin, except the head, abdomen, and along the basis of the marginal fins.

There cannot be much risk of error in considering these specimens as the fruit of the preceding spawning season. If spawned in April they would be four months old. Other specimens were obtained during the Survey ranging in length from 56 mm. to 180 mm. (2 inches to $7\frac{1}{5}$ inches). One series of these, taken also in August, were from 75 mm. to 130 mm. in length (3 to $5\frac{1}{5}$ inches). These were taken in Ballinskelligs Bay in shallower water, about 30 fathoms, and may be considered to be in their second year.

In the Irish Survey the smallest mature male was found to be 10 inches long, female 12 inches, while the minimum sizes of fish actually ripe were 10½ inches and 12 inches respectively. As the minimum of the *spent* fish is not mentioned, the numbers of specimens to which the above figures refer are 100 males, 34 females. No effort has yet been made to discover the maximum size of immature specimens.

The Scaldfish or Scaldback (*Arnoglossus laterna*).

Distinguishing Characters.—This fish differs from the top-knots in its less shortened form, and smaller mouth, which is scarcely larger than in plaice or dabs. Its most striking peculiarity is the delicacy of the skin, which has given it its common name. Friction in the trawl always removes nearly all the skin, leaving the flesh bare as though the fish had been scalded. The scales are very thin, those of the upper side larger and having a row of minute spines along the posterior edge ; those of the lower side smaller, without spines. The fin-rays are numerous, 87 to 101 in the dorsal, 64 to 78 in the ventral. The dorsal commences on the snout. The teeth are small and in a single row. In the males above 5½ inches long the dorsal rays from the 2nd to the 6th inclusive are much elongated, and likewise those of the pelvic fin. This occurs to a slight extent in the females above the same size, but is absent in both sexes below that size.

Names.—This fish is called the megrim by Couch, and apparently this name is applied to it in Cornwall, not to the *Lepidorhombus megastoma ;* it is also called the lantern-fish ; but scaldfish is the most convenient and appropriate name for it.

Habitat.—Mediterranean to Norway. Has been found on the east coast of Ireland as well as on the west, and in the Firth of Clyde ; it is rare, if not very rare, off the east coast of Scotland and in the North Sea.

Size.—The largest specimens (males) were 8 inches long, taken near Plymouth. The food has not been ascertained.

Breeding.—Spawning occurs in April and May, and perhaps

June : it has not been carefully studied. A ripe male was found in April on the west of Ireland.

The Eggs and their Development.—Raffaele reports that the eggs of *Arnoglossus* are like those of turbot and brill, having a simple yolk and a single oil-globule, but smaller, measuring only 0·6 to 0·7 mm. across ($\frac{24}{1000}$ or little more, about $\frac{1}{40}$ inch). The larva of this species has not been traced.

The smallest specimen obtained in the Irish Survey (Fig. 128) was 25 mm. (1 inch) long. Many scales were still in the skin, and it was doubtless provided with them all over during life. In the preserved specimen there was not much pigment, only patches of black specks here and there. This specimen was

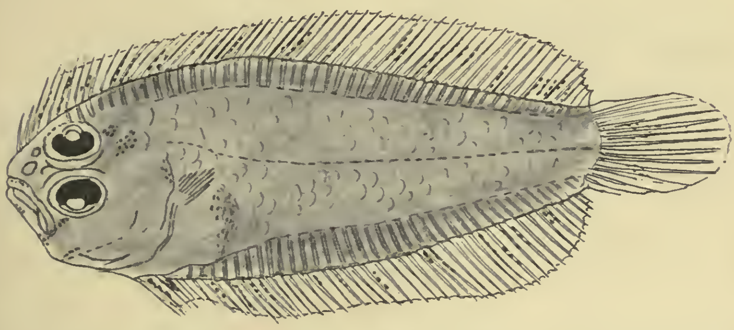

FIG. 128.—Young Scaldfish, 1 inch long. From a preserved specimen ; after Holt.

taken at 41 fathoms in August ; it may have been spawned the same year. In Cawsand Bay, Plymouth, young specimens are abundant. In October they were obtained of the length of 2·8 to 3·4 cm. (1·1 to 1·4 inch) and probably four or five months old. In February others were 4·5 to 6·3 cm. (1·8 to 2·5 inches), and these would be eight or nine months old. Older specimens were abundant from May to September, and ranged from 1·9 to 5·4 inches. The larger of these must have been two years old, the smaller one year. In December forty-three specimens 5·8 to 8 inches were obtained from trawlers fishing from ten to twenty miles from the coast : these were two or three years old and upwards, and were sexually mature. In September thirteen specimens only 3·15 to 4·7 inches were taken eight to ten miles south of the Eddystone, in 36 to 38 fathoms, so that the immature specimens are not confined to shallow water.

A ripe male has been seen only 4½ inches long, the smallest mature female may be a little larger. It is to be noted that the males may be ripe before the elongation of the fin-rays takes place, just as a man's beard does not fully develop until long after puberty.

The Top-knots (*Zeugopterus punctatus*, *unimaculatus*, *norvegicus*).

Distinguishing Characters.—All have short faces, no free root to the tails, and very long dorsal and ventral fins. The hinder ends of these fins are continued on to the blind side beneath the root of the tail. The dorsal commences on the snout in front of the eyes, and the ventral and broad pelvic occupy the whole ventral margin forward to the gill opening. The vent is very far forward. The mouth is large, and the gape almost at right angles to the length of the body. The scales are very spiny, and the spines are long and project up from the surface of the skin giving a rough hairy appearance.

The first kind, called browny or bastard brill by Devon and Cornish fishermen, is the roughest of the three, and its ventral fin is united with its two pelvic, the vent opening between the latter. The lower side is rather smooth. Fin-rays, dorsal 87 to 101, ventral 69 to 80.

The second kind has the first dorsal-ray elongated, the ventral is not united to the pelvic; there is a single dark spot in the centre of the hinder part of the upper side; the lower side is rough.

The third kind is less shortened and less rough, the scales being less spiny and not projecting so much. There is no elongation of the first fin-ray of the dorsal, no fusion of the ventral and pelvic fins, little roughness on the lower side.

Names.—The three kinds may be called respectively the common top-knot, the one-spotted top-knot, and the Norwegian top-knot.

Habitat.—The first and largest form extends from the Bay of Biscay to the north coast of Europe, the second from the Mediterranean to the Shetlands, and the third from the English Channel to Norway. The first and third are fairly common in the neighbourhood of Plymouth, and in the estuary of the Clyde, and *punctatus* has also been taken on the east coast of Britain and east coast of Ireland. *Norvegicus* occurs on the west coast of Ireland, and so also does *unimaculatus*. They are usually found in sandy bays, and taken in shrimp trawls. But as they are known, *punctatus* and *unimaculatus* at least, to have the power and habit of clinging to the surface of rocks, and do not burrow in soft ground, it is probable that they are much more abundant

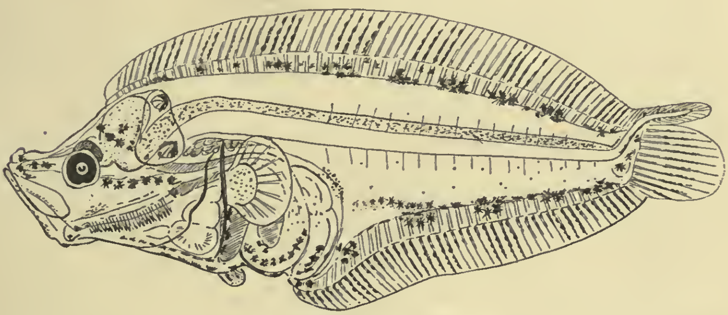

FIG. 129.—Larva of the largest Top-knot, a little more than $\frac{3}{8}$ inch long, from a preserved specimen; after Holt.

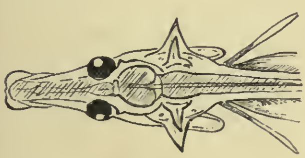

FIG. 130.—Head of the specimen shown in Fig. 129, viewed from the dorsal edge, and showing the projecting spines in the region of the ears; after Holt.

than they seem to be, but for the most part escape capture. They adhere to the surfaces of the slate or glass sides of aquaria by a constant waving motion of the hinder parts of the marginal fins, which pumps out the water from beneath the body, and so causes a pressure on the outside. They remain stationary thus for hours, and from their dark colour are difficult to distinguish on a dark surface.

Breeding.—Ripe eggs were obtained from a specimen of *unimaculatus* 5 inches long, in June, in Loch Fyne. They were buoyant and resembled those of the turbot, but were smaller;

they were not fertilised, but measured ·96 mm. in diameter when preserved. The yolk is simple and transparent and contains a small yellowish oil-globule.

A ripe specimen of the smallest species, *norvegicus*, was obtained at a depth of 25 fathoms, near the Eddystone, in March, 1892. It was $3\frac{1}{3}$ inches long. The eggs were ·9 mm. in diameter ($\frac{3.6}{100}$ inch) and contained a single oil-globule.

Certain remarkable larval and transforming specimens were taken in the Irish Survey, off the coast of Donegal, at depths between 14 and 22 fathoms, in May, 1891. They ranged in length from 5·8 to 10·6 mm. (from a little less than $\frac{1}{4}$ inch to a little more than $\frac{2}{5}$ inch). The appearance of the largest specimen as seen after being preserved in spirit, and then made transparent, is shown in Fig. 129. The chief peculiarity is the presence of two sharp long spines projecting outwards from the region of the ear; these are not easily seen when the fish is seen from the side, but their appearance when it is viewed from the edge is seen in Fig. 130. Two specimens of this same larva were taken at Plymouth in May, and brought alive to the laboratory; they were captured by hand in a tide-pool at the breakwater. From the number of the fin-rays and appearance of a specimen in a more advanced stage of transformation than that figured, there can be little doubt that these specimens are the larvæ of the largest top-knot, *Zeugopterus punctatus*. Other similar specimens of smaller size and without the spines have been described, and probably belong to the one-spotted top-knot.

THE COD FAMILY.

LIKE the flat-fishes, all the kinds of fish in this family are without spiny fin-rays, and generally speaking without spines or bony armour ; they carry no weapons either for offence or defence except their powerful jaws and teeth. The fin-rays are all soft and flexible, and even the scales are but slightly developed, being small, smooth, and thin, and usually easily detached from the soft skin. The dorsal and ventral fins together extend along a great part of the length of the fish ; the tail fin is separate. In some there are three dorsals and two ventrals, as in cod, haddock and others ; in some there are two dorsals, a long one behind and a short in front, and a single ventral, as in the ling and hake ; in some there is only one long dorsal and one ventral, as in the tusk. The pelvic fins are on the throat in front of the pectoral or breast-fins. The eyes are large, and in many kinds there are barbels on the lips or chin.

The fishes of this family belong more especially to the Arctic and Antarctic regions and the temperate zones, but are almost entirely absent in the tropics. They feed for the most part on or near the bottom, and the majority of them abound in the shallower waters less than 200 fathoms, although there are a few deep-sea species belonging to the ocean abysses. The majority feed in the day-time, hunting their prey by sight, and as they are voracious, rapacious fish with large mouths, and haunt the sea-bottom, they are taken by hook or trawl with equal success. Their food is various, consisting both of other fishes and of the lower marine animals, especially crustacea. One species, the burbot, lives entirely in fresh water.

The following are the British kinds of the cod family with their chief peculiarities :—

I. Species with three dorsal fins and two ventral, body not much elongated.

1. **The Cod.**—Grows to a large size: the upper jaw is the larger, its outer row of teeth enlarged, and there is a barbel on the chin. Colour, greenish yellow or olive, with numerous small dark spots ; lateral line white.
2. **The Haddock.**—Smaller, but similar, distinguished by the absence of small spots, by a black blotch on the shoulder, and a black lateral line. Barbel small.
3. **The Bib, Pout,** or **Whiting Pout.**—Smaller, very deep in the body, copper-coloured with broad upright dark bands. Barbel present.
4. **The Poor-cod.**—Smaller, not so deep in the body, vent further back : brownish yellow on the back, without bands. Barbel present.
5. **The Whiting.**—No barbel. Sides silvery, a dark spot at the root of the pectoral fin.
6. **The Coal-fish.**—Differs from the preceding in having the lower jaw longer than the upper : teeth in the upper jaw of equal size. A small barbel. Colour dark slate-blue, almost black on the back and sides ; lateral line white.
7. **The Pollack.**—Like the preceding, but has no barbel, and the lower jaw longer. Colour, a dull green.
8. **The Poutassou.**—Outer row of teeth in both jaws enlarged, second dorsal fin short ; body narrow, silvery ; lower jaw slightly longer than the upper.

II. Species with two dorsal fins, the hinder long, the front one short : one ventral fin.

9. **The Ling.**—A barbel on the chin. Body elongated, scales minute, fins narrow, very flexible.
10. **The Hake.**—No barbel, scales larger, fins broader and stiffer ; teeth larger.
11. **The Fork-beard.**—A barbel on the chin. Pelvic fin forms a long forked filament extending behind the vent.
12. **The Burbot.**—Closely resembles the ling, but the body is broader behind the head, and the scales are larger. The fish is much smaller,
13. **The Lesser Fork-beard** or **Tadpole fish.**—First dorsal fin very small, rudimentary. Head flattened and fleshy.

III. Species in which there is no separate first dorsal, but the front part of the single dorsal is a narrow fringe kept vibrating during life.

14. **The Three-bearded Rockling.**—Two barbels on the upper lip, one on the chin. Marked in the full-grown state with black or brown round spots.
15. **The Four-bearded Rockling.**
16. **The Five-bearded Rockling.**

IV. Species in which there is one long dorsal fin and one long ventral.

17. **The Torsk** or **Tusk.**

Amongst these, those kinds which are provided with a single barbel on the chin feed chiefly on the bottom, their habit being to swim with their heads inclined to the ground, continually feeling the latter with the barbel. These fish eat both fish and lower animals, especially crustacea. The ling is an exception, it has a long barbel but feeds almost entirely on active fish. The explanation of this seems to be that the ling is a somewhat nocturnal fish which haunts rocky ground and conceals itself in the clefts and holes of the rocks. Its habits probably resemble those of the conger and rocklings, and its barbel is of use to it as a sensitive tentacle to feel its way about, and not to find crustacea or other animals on the ground. Its elongated shape corresponds to the habit of concealment. The ling is not taken in the trawl so commonly and in such large numbers as the cod is.

The habits of the rockling are known from observations on specimens in confinement and on the shore. They are entirely nocturnal and self-concealing fish, remaining under stones or in crevices among rocks except when they perceive the neighbourhood of prey or food, the presence of which they recognise by smell rather than sight. They use their barbels for feeling about on the bottom when seeking their food.

Those fishes of this family which have no barbel feed more on swimming creatures than on those that walk or crawl, and the kinds that prey most largely on migratory fish which swim near the surface are those which have a projecting lower jaw. This is the case particularly in the pollack, to a less degree in the coal-fish, but the hake although its lower jaw scarcely projects at all feeds chiefly on surface fish such as pilchard, herring and sprat.

The eggs of the fishes of this family are all of the buoyant kind, with the single exception of the burbot, whose eggs are shed loose and separate at the bottom of the sluggish fresh-water streams which it inhabits. Apart, however, from the fact that they develop at the bottom of the water the eggs of the burbot are quite similar to those of the rocklings, and these would also sink in fresh water. There is a great similarity between the eggs of the cod family and those of the flat-fish family. All the members of the first group in the list given above (species of the genus *Gadus*) have eggs in which the yolk is quite simple and without oil globules: these eggs agree in these respects with those of the small-mouthed flat-fishes, plaice, flounder, dab, &c. (species of *Pleuronectes*). It is almost impossible to distinguish these eggs from one another at the early stages of development; the only differences among them are slight differences of size, and in some cases even these are wanting. The remaining members of the family all have eggs with a single oil globule, like those of the left-sided flat-fishes, turbot, brill, &c. There are no eggs in the cod family corresponding to those of the soles.

The larvæ are always distinguished by the fact that the hinder end of the gut is situated at a distance from the edge of the fin-membrane. The young in the third or adolescent period have various habits. Those of the rocklings are entirely surface swimmers, having for a time a bright silvery skin like that of the sprat or herring. The young of other kinds are found near the bottom or among the sea-weeds and rocks of the shore. The very young stages of cod, haddock, &c., are often found lurking under the broad swimming bells of large jelly-fishes which are so abundant near the coasts in summer, but when they get a little larger they abandon the surface of the open waters and seek the shore and the bottom. The young of cod, whiting, pollack, and coal-fish are all found near the shore in their first year, and a little further out in their second, while those of the haddock, hake, and ling are not found close to the shore, and only exceptionally in moderately deep water; these species are reared in the deeper and more distant waters.

The Cod (*Gadus morrhua*).

Distinguishing Characters.—The body of the cod is thick and rounded in front, the tail rapidly diminishing in thickness towards its end. The ventral fin begins beneath the fourth or fifth ray of the second dorsal, and the hinder edge of the tail-fin is straight or very slightly curved inwards. The mouth is large, the angle of the jaw being behind the front edge of the eye. The cod reaches and sometimes exceeds the length of 5 feet, and weighs from 30 to 50 lbs.

Habitat.—On the European coast from the Bay of Biscay to the north of Norway, and on the American coast from Greenland and Iceland to New York. It is not found abundantly beyond a depth of 120 fathoms.

Dr. Fulton found that the females were more numerous than the males, but not so large: the difference in length however was not great. The proportions are 133 females to 100 males in number, in length 95 to 100.

On the east coast of Scotland, according to the observations of the Fishery Officers, ripe cod are found in every month from January to June inclusive, but the numbers of individuals in this condition are very small except in the three months, February, March, and April, which form therefore the chief spawning period. At the Lofoten Islands, Sars found the spawning taking place chiefly in March and April.

The fish seem to approach the coast in order to shed their spawn, at any rate in the Lofoten Islands, where the declivity of the sea-bottom is very rapid. Off the Yorkshire coast in the neighbourhood of Flamborough Head, twenty to forty miles out, large numbers of spawning cod are taken by the trawlers in February and March, and along the east coast of Scotland the cod spawn within these distances and beyond.

The egg of the cod is like that of the plaice and flounder, &c., having a simple yolk without any oil globule, and only a small space between the yolk and the egg-membrane. It is 1·39 mm. (little more than $\frac{1}{20}$ inch) in diameter, almost exactly the same size as the egg of the lemon dab, from which it could scarcely be distinguished in the earlier stages of development.

Development usually takes place naturally, on account of latitude and season, in cold water. At a temperature of 45° F. the eggs hatched in twelve days at the Marine Station at Granton, and in thirteen days at about the same temperature in the United States, while at 38° they were not hatched till the 20th day.

The newly hatched larva is a little over 4 mm. in length ($\frac{4}{25}$ inch). With other species nearly allied such as whiting, haddock, it agrees in the fact that the gut ends behind the yolk at some distance from the edge of the fin-membrane; while it differs from these other species in having four bands of black pigment on the body, one at the region of the pectoral fins, one at the hinder end of the yolk, two on the tail. There is no pigment on the fin-membrane. In larvæ a little older the fin-membrane instead of being flat throughout its length expands into a wide bladder over the head: this disappears again at later stages. Fig. 56, p. 103, shows the character of the larva when ten days old, but the limit of the bladder over the head is not indicated.

Sars investigated the growth and development of the young cod very carefully in the neighbourhood of the Lofoten Islands in 1866 and 1867. In the former year he commenced his observations on May 7th, when he found that the spawning was finished, and large numbers of fry were hatched. On May 20th he was able on a calm day to see numbers of the fry near the surface of the water; they were about one-third of an inch in length, and were very transparent. All that could be seen distinctly from a boat was the comparatively broad head with the eye projecting on each side, while the rest of the body appeared like a fine thread vibrating constantly. These little fry were feeding on very minute crustaceans, which swim near the surface. On June 12th he had another opportunity of watching the young cod fry in the sea. They were considerably larger, measuring nearly an inch in length, and had to some extent advanced from the larval or primitive condition to that of a perfect fish. The primitive fin which runs unbroken round the hinder end of the body had partly divided into the first two of the fins on the back which are seen in the grown fish, and the characteristic barbel on the chin had begun to show itself as a little projection.

After this bad weather set in, and for some days Sars was unable to make observations in the sea. On June 23rd he found a few of the young cod, but the majority had disappeared. On

July 5th he made the discovery that the little fish were sheltering themselves under large jelly-fishes which were very abundant, and he caught numbers of them. He found that they practised this habit for the sake of the crustacean parasites of the jelly-fish, specimens of which he found in the stomachs of the fish. The largest young cod which he caught at this time measured $1\frac{1}{2}$ inches in length and showed already distinct colours, five or six dark streaks running round the body, while the sides showed a silvery or golden gloss.

The next year, on August 3rd, Sars caught young cod-fish swimming in shoals in one of the curious streaks which are formed in the sea by currents, and in which floating weeds, jelly-fishes, and other floating animals often collect in quantities. These fish were about 2 inches in length, or a little more. The fins of the perfect fish were fully developed in these, and also the barbel under the chin, and apparently the scales. In colour they were marked above with lines of square spots of a reddish-brown, the sides being silvery and golden. At this stage then, when the cod are only about 2 inches long, what I have called the second stage of their life is over, and they have reached in all important respects the condition of the perfect fish.

The cod at the Lofoten Islands spawns chiefly in March and April, and these most advanced young were found at the very beginning of August, so that they could not be more than five months old. But even at the earlier stage, at the beginning of July, when only $1\frac{1}{2}$ inches long, and found frequently sheltering under the jelly-fishes, they have practically completed their transformation, and these were found only four months after the commencement of the spawning period. It must be remembered, however, that in the cold water of the Lofoten Islands cod eggs take a long time to hatch. Sars found in vessels kept on shore that the egg hatched in eighteen days, and in the sea the water would be colder, so that we must take off about three weeks for the period within the egg, and we arrive at the conclusion that the little cod, $1\frac{1}{2}$ inches long, which had gone through their transformation, were little more than three months old, if spawned at the beginning of the spawning period, while if they came from eggs shed in April they were not much more than two months.

The development of the cod has been also studied by Professor

McIntosh and Mr. Prince at St. Andrews. They were not able to keep the larvæ alive in aquaria after the supply of yolk was exhausted, but they succeeded in recognising the young forms in various successive stages captured in the Bay. The smallest of these were 5 mm. long ($\frac{1}{5}$ inch) and were taken on April 30th, middle of May, and June 1st. The fin-membrane was still entirely without fin-rays. Others were 6 mm. long. In those of 7 mm. in length fine rays had appeared in the fin-membrane behind; the bars of colour on the tail had spread out and were no longer distinct.

Taken with these were specimens somewhat larger and older, 8 to 10 mm. long or more. At the former length the larval fin is still present and undivided, but at 10 mm. ($\frac{2}{5}$ inch) the permanent fins are marked out and the rays have begun to appear in them, while the original membrane between them is disappearing. Up to this stage the little larvæ had been feeding on minute crustaceans (copepods), and these continue to form their principal food.

Older specimens taken also on June 1st were $\frac{15}{16}$ inch long, and showed the fins more completely developed, and the commencement of the barbel on the chin. The colour of these and larger specimens up to $1\frac{1}{2}$ inches long consists of dark greenish-brown bars irregularly arranged, separated by pale areas. In June and July young cod from $1\frac{3}{8}$ to $1\frac{7}{8}$ inches in length were found abundantly in St. Andrew's Bay; the speckled colour is very characteristic.

Sars found that the young cod after July lived among the sea-weeds on the rocks near shore. In October they were 4 or 5 inches long, in December 6 to 8 inches. These sea-weed cod were of a reddish-yellow colour with thick bodies, and fed chiefly on crustaceans, while others which lived on sandy ground, fed on worms and small fish and were light green or grey, and thinner. During the following summer the year-old cod remain among the weeds and near shore, and measure on an average 12 inches in length. Towards autumn they go out to deeper water, and Sars concludes that the size at which breeding commences, namely about 3 feet in length, is not reached until the fish are three years old.

The young of the cod were reared from the egg in Norway by Dannevig at his well-known establishment at Arendal, but he only recorded their length, and did not make a study of their transformation. He put 500,000 fry, hatched on April 27th, into an enclosed pond of sea water, and on July 12th they measured a little more than 2 inches in length. At this length they must have completed their transformation, and thus the period required for this was two months and a half.

In October these cod measured $4\frac{3}{5}$ inches to $6\frac{2}{3}$ inches, and in the following February 14 to 16 inches. Mr. Holt found that at Grimsby the critical sizes of cod in reference to sexual maturity were 22 to 35 inches; none were mature at a length less than 22 inches, none immature at a length over 35. No difference in this respect was found between males and females. The evidence available indicates that the lowest limit is not reached at one year of age, but it is probably reached by some individuals at two years.

The Haddock (*Gadus aeglefinus*).

Distinguishing Characters.—The barbel on the chin is very short. The vent is further forward than in the cod, the first ventral fin commencing below or very slightly behind the commencement of the second dorsal. The body is narrower than that of the cod. The black blotch on the side is beneath the middle of the first dorsal fin. The sides and back in the fresh fish have a beautiful bronze-coloured reflection; the lateral line is black. A specimen has been recorded which measured 37 inches in length, and weighed $24\frac{1}{4}$ lbs., but the largest of a large number measured for the Scotch Fishery Board was 25 inches long.

Habitat.—From the Arctic Ocean to the Bay of Biscay on the eastern shores of the Atlantic, to Cape Hatteras on the western side. It is not abundant in the English Channel, though said to be taken there in considerable numbers in certain years. Very abundant in the North Sea, in the northern part of which it forms the staple produce of the trawl fishery. More abundant on the north, east, and west coasts of Ireland than on the south.

Food.—The principal food in the Firth of Forth was found to be crustaceans and molluscs; the former were found in 60 per cent. of the stomachs, the latter in 40 per cent. Echinoderms and worms were of nearly equal importance, 29 per cent. of the stomachs containing the former, 23 per cent. the latter. Fish remains were found only in 5 per cent. Of the crustaceans taken the most numerous were common shrimps, and next in frequency were hermit-crabs, swimming crabs, and sand-hoppers. Among the molluscs, common bivalves and the razor shell were most abundant ; the whelk and other univalves, octopus and a kind of small cuttle-fish also occurred. Of the marine worms the sea-mouse (*Aphrodite*) was the most numerous.

On the west coast of Ireland echinoderms occurred most frequently in haddocks' stomachs, crustaceans next, worms next, and molluscs last.

The females are nearly twice as numerous as the males, the proportion being 188 to 100, but the males are slightly larger, in the proportion of 100 to 98. The haddock, like the cod, spawns on the east coast of Scotland in February, March, and April. The spawning fish are found from five miles off the coast upwards, and at depths of 20 fathoms and upwards. On the west coast of Ireland ripe fish were taken at 38 fathoms, 44 fathoms, 80 fathoms, and 154 fathoms, but the mature fish approach nearer the coast in the spawning season.

The eggs closely resemble those of the cod, the only difference being that they are larger, 1·45 to 1·5 mm. in diameter ($\frac{6}{100}$ inch) ; they are thus somewhat smaller than those of the plaice.

The larva when first hatched is a little larger than that of the cod, which it closely resembles. As in the cod only black pigment is visible, and the haddock larva can be distinguished by the fact that the pigment does not form bars across the body, but is confined in the tail to the ventral edge ; it is absent from the fin-membrane and from the yolk-sac.

No careful study of the later larval stages of the haddock has been made. Professor Sars mentions that he could distinguish the little haddock by their shorter and stouter form, and they have been found at a length of 2¾ inches, lurking under large jelly-fishes like the cod. In Dr. Fulton's fine-meshed trawl seven specimens, 1 inch long or less, were taken in one haul in the Moray Firth in July, fifteen miles from the shore at a depth of 30 fathoms, 339 specimens 2 to 5 inches long were taken, the great majority at depths between 20 and 30 fathoms, and from four to ten miles from the coast. Nearly all these were captured in September, and were doubtless the young of the year; they occurred off the entrance of the Firth of Forth. In February, March, and April, specimens 6 to 10 inches in length were taken, but not in large numbers. These are the year-old fish. Dr. Fulton thought that probably the young haddock frequented rocky ground and so did not come much in the way of the trawl.

Mr. Holt's observations in the North Sea tend to confirm the result of Dr. Fulton's, that the young of the haddock frequent grounds at some distance from the coast. In 1892 he obtained specimens a few months old on three occasions, once in July,

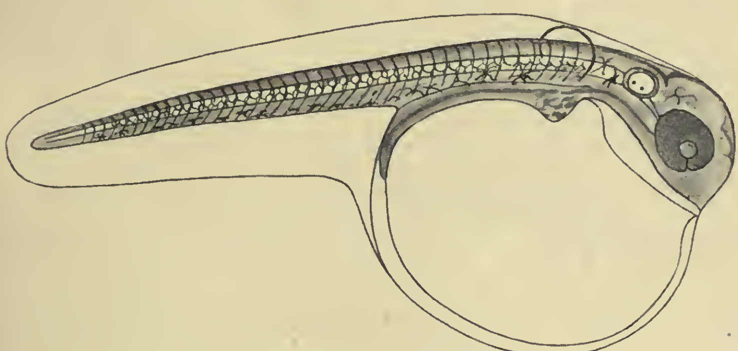

FIG. 131.—Larva of Haddock, just after hatching.

twice in August. On the first occasion two specimens were taken, $2\frac{1}{4}$ to $3\frac{1}{2}$ inches long, at 30 fathoms on the inner shoal of the Great Fisher Bank amongst the sea-mat (*Flustra foliacea*), which was brought up by the trawl. As this was a deep-sea fishing trawl of large mesh there may have been a very large shoal of these young haddocks on that ground, the two taken having been only accidentally entangled in the "weed." In August thirty-nine specimens altogether were obtained, $3\frac{3}{16}$ to 5 inches long, captured fifty-four to sixty-one miles east of Spurn Light Vessel at 16 to 20 fathoms. No specimens were taken by the inshore fishermen in the Humber.

The investigation of the limit in size between maturity and immaturity has not been so thorough in the case of the haddock as in others, but both sexes seem to be often mature at 11 or 12 inches, while some females were immature at 16 inches. We may consider 11 to 16 inches about the length reached at two years of age.

According to Mr. Holt's experience, when the fish of the year are taken, less than 5 or 6 inches in length, no large fish are captured, and he believes that the haddock swims in shoals, the older fish separate from the younger. The smaller fish in the catches made by the trawlers are 10 to 13 inches long, and the proportion of these was noticed to decrease in summer and increase in autumn and winter. Mr. Holt suggests that the reason of this is that the shoals of full-grown or large fish are recruited at this season of the year from the small fish which have grown large enough. But it seems that the recruits must be at the end of their second year, as very few if any probably reach 10 inches at the end of their first year.

Whiting (*Gadus merlangus*).

Distinguishing Characters.—No barbel on the chin; the black spot is above and about the root of the breast fin. The vent is further forward than in the cod or haddock, the first ventral fin commencing beneath the middle of the first dorsal. The tail-fin ends with a straight or very slightly incurved edge. The largest whiting recorded by Dr. Fulton was 21 inches long; the weight of large fish is usually from 3 to 4 lbs.

Habitat.— From Norway to the Mediterranean. More abundant and larger off the south coast of England than in the North Sea, but occurring in numbers round all the coasts of Britain and Ireland. On the west coast of Ireland it was not taken at a greater depth than 40 fathoms, and it is restricted to the neighbourhood of the land more than cod or haddock.

Food.—Five hundred and thirty-nine stomachs containing food, from whiting taken in the Firth of Forth, were examined. The principal food was fish and crustacea, 65 per cent. of the stomachs containing the former, 37 per cent. the latter. Of the crustacea, only the common shrimp and the red shrimp occurred abundantly; of the fish, herrings and other whiting were most frequent. The whiting is thus strongly addicted to cannibalism.

The excess in number of the female sex is a little greater in the whiting than in the haddock, namely, 211 to 100; the females are slightly larger, but the difference is not important, the average length of females to that of males being as 104 to 100.

On the east coast of Scotland the whiting spawns a little later than the haddock and cod, the months being March, April, May, and June. On the west coast of Ireland, March and April were the principal months, and near Plymouth spawning begins in February. The ripe fish are found at no great distance from the shore and at no great depth, from two or three miles upwards, and from 10 fathoms upwards.

The eggs resemble those of cod, haddock, &c., but are smaller than those of the cod, measuring 1·07 to 1·25 mm. in

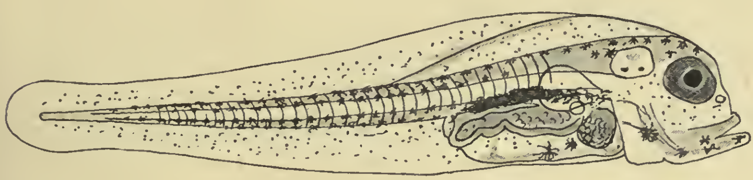

FIG. 132.—Larva of Whiting after absorption of the yolk, from a specimen hatched in the aquarium; after Prince.

diameter. The fish spawn every year in the Plymouth Aquarium and the eggs are hatched without difficulty.

The larva when first hatched is 3·6 mm. long, a little smaller than that of the cod. It has been hatched from eggs taken from the fish both at St. Andrews and at Plymouth. As in cod and haddock the black pigment is confined to the body of the larva, but in the whiting there are yellow pigment-specks on the yolk-sac and fin-membrane. The recognition of the eggs and larvæ of these different fish, cod, haddock, whiting, &c., when taken from the sea is a matter of some doubt and difficulty, because of the close similarity. The larvæ have been reared in confinement for some days after the yolk was absorbed. There is a large distension of the skin over the head, as in the cod. The black pigment-specks at these stages extend without a break along the upper and lower edges of the body.

According to McIntosh and Prince the young whiting taken in St. Andrew's Bay can be recognised from the length of 15 mm. ($\frac{3}{5}$ inch) upwards; they are distinguished from young cod by the more abundant pigment and the much greater extent of the first ventral fin, already formed at that size. At lengths from $\frac{4}{5}$ to $1\frac{1}{5}$ inches, a small but distinct barbel is present, although it is absent in the adult whiting: it is much shorter than in cod of the same length, and disappears at a length of about 3 or 4 inches.

The young whiting of the year are found in great abundance close to the shore, and in bays and estuaries. In fact they are like the plaice in this respect, and get in the way of shrimp nets and inshore fishing everywhere in hundreds and thousands. In the course of Dr. Fulton's special search for small fish with a fine-meshed trawl, whiting were far the most abundant of the young fish captured; over 26,000 were taken as compared with only about 1,000 young plaice. The region of the young whiting, however, is rather farther from the shore and in greater depth of water than that of the young plaice. In Dr. Fulton's investigation in 1889, an immense shoal of young whiting were found in the Firth of Forth, extending from Inchkeith to some eight miles east of the Isle of May, over 3,000 specimens being sometimes taken in one haul of the trawl. Nearly all these fish were from 2 to 5 inches in length, in September, and must have been four to six months old. At the mouth of the Humber, at the beginning of September, 254 whiting $2\frac{3}{4}$ to 5 inches long were taken in the shrimp trawl. In the shrimp fishing of the Lancashire coast also large numbers of young whiting are taken, the largest hauls in July and August. At Plymouth, although full-grown whiting are very abundant, I have not ascertained where the young of the year are most plentiful: I have taken them in the trawl in Whitsand Bay at 3 to 5 fathoms, and in a midwater net just outside the Eddystone: these were specimens 2 to $3\frac{1}{2}$ inches long taken in June and July.

It is not surprising that young whiting should be taken by shrimpers, since they are engaged largely in feeding on the shrimps and other small crustacea. In Lancashire Professor Herdman found in 116 cases of recognisable food among whiting 3 inches long and upwards, that crustacea occurred in 73 per cent., fish, namely sprats and sand eels, in 24 per cent., while other kinds of food were unimportant.

The young whiting are scarcer in shallow waters in winter; they pass out on to deeper grounds with the cold weather. Fulton found that in February, March, and April the majority were 5 or 6 inches long, which may be taken as the length at one year of age.

The smallest mature whiting on the east of Scotland were 9 inches long in both sexes, and this length is doubtless reached by many at two years of age.

The Coal-fish (*Gadus virens*).

Distinguishing Characters.—The lower jaw is only slightly longer than the upper, the barbel is rudimentary. The first ventral fin commences beneath the last rays of the first dorsal, and ends below the end of the second dorsal. The body is not much compressed and not very deep from the back to the belly, but rather slender. The colour on the back is dark, almost black, the lateral line white. It grows occasionally to 43 inches long, the usual length being between 2 and 3 feet.

Habitat.—From the Arctic Ocean to the Mediterranean. In the British Islands more abundant on the more northern coasts, very plentiful in the Orkneys and Shetlands and on the east coast of Scotland. It extends to 70 fathoms.

Names.—This fish in its younger stages being very abundant and familiar on the coasts of Scotland and Ireland, has an extraordinary variety of local names. Green-cod, saithe, and sillock are the most commonly used; in Yorkshire the young are called blue-backs.

Breeding.—It spawns in February, March, and April, but not being taken in large numbers in the trawl, and ripe specimens not being usually taken on lines, the spawn has not been so easy to obtain as that of other species. The fertilised eggs have however been examined in the living condition at St. Andrews. They are similar in character to the eggs of the cod, but smaller, being only 1·02 mm. in breadth, or scarcely more than $\frac{1}{25}$ inch. The hatched larva was much like that of the cod.

The larvæ and transformation stages are to be found near the surface of the sea, but have not been traced. The young from 1 inch in length upwards are well known: in their first summer they swarm around rocky weed-covered shores, and are seen in numbers about the piers of harbours. At the same time larger specimens about a year old are seen and easily caught with hooks in harbours and up to a certain distance from the shore. The limits of size of the year-old fish have not been definitely ascertained, but many of them are only from 4 to 7 inches long. The size at which spawning commences is also uncertain.

Thus there is no doubt that the young of this fish live near the shore, while the adults roam far out to sea and to considerable depths. In the Irish Survey 164 specimens under 4 inches in length were taken, all at depths less than 5 fathoms, while 43 adults over 30 inches in length were taken at 70 fathoms. As in the case of other species, the young live principally on the small crustacea which abound among the sea-weeds or on the bottom, while the older fish feed principally on other fishes, in the North Sea especially on the herring. In the young fish the upper jaw is longer, and the barbel is well developed, but beyond a length of about 12 inches the lower jaw becomes the longer and the barbel a mere rudiment, a change which corresponds to the change of habits and food.

The Pollack (*Gadus pollachius*).

Distinguishing Characters.—Lower jaw longer than in the coal-fish, no barbel, body deeper, and the colour green instead of blue or nearly black. It grows to 3 feet in length or more, but is usually seen between 18 inches and 30 inches.

Habitat.—From Norway to the Mediterranean ; in the British Isles commonest on the south coast, especially off the shores of Devon and Cornwall. It has not been taken at depths greater than 40 fathoms.

Food.—In the Irish Survey the larger pollacks were found to have only other fishes in their stomachs, namely sand eels, sprats, scald-fish, gurnard, and others. The younger specimens contained crustaceans, worms, and molluscs.

Breeding.—On the west of Ireland pollack were found to be ripe in April and May. In Shetland ripe fish were obtained in

May, but on the coast of Cornwall spawning appears to commence in March, or perhaps in February, the young of the year being found at the beginning of April. The eggs were examined in the Irish Survey, and found to be buoyant and like those of the cod, haddock, and whiting, resembling the latter closely in size. The eggs were not hatched.

In Cornwall I have seen the young pollack in numbers only $\frac{8}{10}$ to 1 inch in length in April, and estimated their age at about six weeks. In October I have taken a number in Cawsand Bay, $3\frac{4}{5}$ to $4\frac{2}{5}$ inches long, and have no doubt these were hatched in the preceding spring. The pollack caught in Plymouth Sound in June and July are 12 to 15 inches long, and are probably in their third year, but as the size at which maturity commences has not yet been ascertained, it is difficult to estimate the later growth.

In the Irish Survey all young pollack under 10 inches were taken at depths less than 5 fathoms. Pollack, whether young or adult, are almost always found in the neighbourhood of weed-covered rocks.

The Ling (*Molva vulgaris*).

Distinguishing Characters.—Several large teeth in the lower jaw and palate. The barbel is nearly as long as the lower jaw. The ventral fin commences beneath the seventh or eighth ray of the second dorsal. The tail fin has a rounded edge. The dorsal, ventral, and tail fins, are darker towards the margin, but edged with white. Usually the back is a uniform grey, and the belly light, but some specimens have large rounded black spots on the back and sides. The ling is said sometimes to reach 7 feet in length, its usual length is from 4 to 6 feet.

Habitat.—From Spitzbergen to the Straits of Gibraltar, on the east, and Newfoundland on the west. It is abundant all round the British and Irish coasts, but most plentiful in the northern parts of the North Sea, about the Orkneys and Shetlands, and the Faroe Islands. On the west coast of Ireland, mature ling were taken in summer at various depths between 5 fathoms and 150, but the greatest number between 30 and 60 fathoms.

Food.—The ling appears to feed almost entirely on other fish.

Forty-one stomachs containing food were examined in the Irish Survey, and fish were found in thirty-three: mackerel in six, flat-fish (megrim and dab) in three, gurnard and haddock each in two, scad and Norway pout in one. A Norway lobster was found in one, and cuttle-fishes and a kind of octopus (*Eledone*) in eight.

Breeding.—The proportion of the sexes in size has not been ascertained, but in number they appear to be very nearly equal.

According to the records of the Fishery Officers in Scotland, the ling spawns in April, May, June, and July, principally in the latter three months.

The egg is 1·08 mm. in diameter ($\frac{1}{25}$ inch), and has a single large oil globule with a pale green colour. Eggs artificially fertilised at sea were hatched at St. Andrews. The larvæ hatched out on the ninth day. They were about 3 mm. ($\frac{3}{25}$ inch) long,

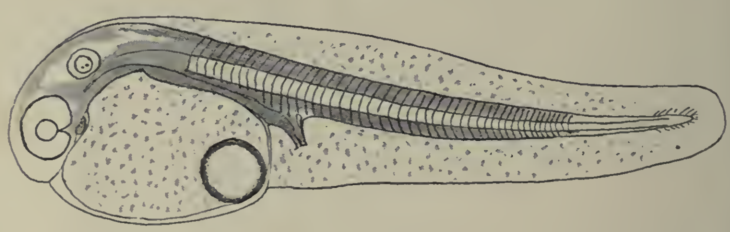

FIG. 133.—Newly hatched larva of the Ling, alive and magnified; after McIntosh.

and were very delicate and transparent. A peculiarity about them is that the head and neck are much bent down over the front of the yolk (Fig. 133). There are black pigment specks on the body, and greenish-yellow specks on the yolk-sac and marginal fin-membrane.

When a week old the larva measures 3·3 mm. ($\frac{13}{100}$ inch), and has a pretty and characteristic appearance under the microscope (Fig. 134). The yolk is not quite all absorbed: the black pigment, in the form of rather large stars, extends along the edge of the back and ventrally, and towards the tail extends into the fin-membrane, while the greenish-yellow specks are very numerous. The mouth is open, but the jaws not developed.

The intermediate stages of the ling are remarkable for the elongated throat fins, which reach back behind the vent. In colour the fish in these stages are greenish on the back, and as soon as the fin-rays appear they can be recognised by the arrangement of the fins. Specimens in these stages, $\frac{2}{5}$ inch, $\frac{3}{5}$ inch, and $\frac{4}{5}$ inch long, were taken off the Isle of May (Fig. 135) in July and August. They were captured in a large tow-net in mid-water, or not far from the surface, and it appears from this that for about the first two months of its life the young ling resembles in its habits the

FIG. 134.—Larva of Ling thirteen days old, alive and magnified; after Prince.

young of the rocklings. The next stage seen was that of a specimen $3\frac{1}{2}$ inches long, stranded on the shore in December. In this, the chief peculiarity was that the colour was in stripes along the body, an olive-brown band passing along the side, a white band above this, and a narrow line of dull orange along the middle of the back. The barbel was long. The history of the ling after this stage is not well known. Specimens from $7\frac{3}{4}$ to 12

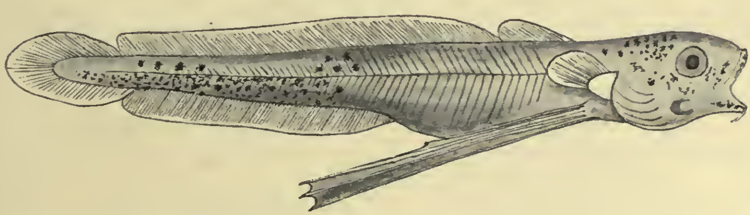

FIG. 135.—Transformation stage of the Ling, $\frac{4}{5}$ inch long; after Prince.

inches long occur not uncommonly off the mouth of the harbour at St. Andrews, and are caught by line fishermen in the neighbourhood. At this stage the stripes are broken up into large irregular blotches. These small fish occur in summer, and are about a year old. During the Irish Survey, of 203 ling caught only six were under 24 inches in length, and these occurred at depths between 16 and 55 fathoms, as many in the deeper as the shallower water. The size at which it becomes sexually mature has not been ascertained: a female, 30 inches long, has been found to be half ripe.

The Hake (*Merluccius vulgaris*).

Distinguishing Characters.—Mouth large, teeth pointed, in two rows in the jaws, and present also on the palate. The first dorsal fin somewhat triangular, higher than the second. The hinder portion of the second dorsal and ventral fins broader than the rest. The ventral fin commences beneath the third or fourth ray of the second dorsal. Dark grey along the back, lighter on sides and belly: inner surface of mouth and gill cavities black. It grows to 4 feet in length, but the more usual size is 2 or 3 feet.

Habitat.—From Norway to Maderia and throughout the Mediterranean, and also on the American coast as far south as Cape Hatteras. It is more abundant on the south coast of England and Ireland than on the other coasts of the British Isles. It is not caught on the east coast of England and the neighbouring parts of the North Sea, but is plentiful in the Skagerack and on the west coast of Denmark in May and June. It is a deep water fish, having been taken at depths up to 400 fathoms; and it is also oceanic, only approaching the coast occasionally. It appears to be true of the more oceanic migratory fish generally, as of hake and mackerel, that they are found in abundance off the south-west of England, the western shores of Ireland and Scotland, and the coast of Norway and northern parts of the North Sea, but penetrate less commonly into the shallower enclosed waters of the Irish Sea and southern part of the North Sea. Their visits to these enclosed seas take place in summer, and they are not found there in winter. On the coasts of Devon and Cornwall hake are most abundant in autumn and winter.

Food.—The hake feeds almost entirely on fish, following and preying upon shoals of herrings, mackerel, pilchards, sprats, and anchovies. Brittle-stars were found in one specimen in the Irish Survey. According to Day the hake is a nocturnal fish, retiring to the bottom of the sea where there is less light in day-time and pursuing its prey in mid-water or near the surface at night.

In the Irish Survey, of twenty-two specimens examined thirteen were females, nine males. Spent or ripe females were taken in March, April, May and June. Ripe or nearly ripe fish were obtained at 25 to 80 fathoms.

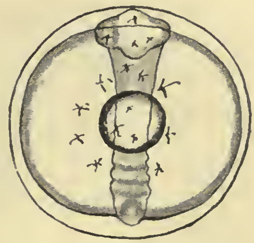

FIG. 136.—Egg of Hake, magnified; after Raffaele.

The eggs of the hake were artificially fertilised and examined at the Naples laboratory. They were ·94 to 1·03 mm. in diameter ($\frac{1}{25}$ inch) with a single oil-globule (Fig. 136). The larva hatched in less than three days, and had an elongated yolk-sac with the oil-globule at its hinder end (Fig. 137). The pigment was yellow and black, the latter absent from the fin-membrane and forming two bands on the tail.

During the Irish Survey, three small hake, 1¼ to 1½ inches long, were taken at 80 fathoms in a shrimp trawl in August. Of larger fish which may be considered to be nearly a year old, one 7½ inches was taken at 40 fathoms and one 6 inches long at 115

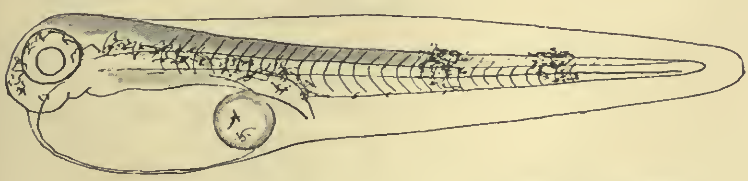

FIG. 137.—Larva of Hake, newly hatched, magnified; after Raffaele.

fathoms in March, two 8 inches long at 53 fathoms in May. All these were captured in trawls, but it is certain that neither young nor mature hake feed only on the bottom. Small specimens are frequently taken in mackerel nets, which shows that like the adults they roam about after prey in mid-water at night.

The Rocklings (*Motella tricirrata, cimbria, mustela*).

Distinguishing Characters.—The barbels, and the narrow anterior fin sunk in a groove in the back, are sufficient to distinguish these fishes. In the three-bearded species the barbels are long, one at the chin, one on each side of the snout in front of the nostrils : in the four-bearded there is one also on the upper lip, in front of the other pair, while in the five-bearded there is one pair on the anterior nostrils and a pair on the upper lip. The three-bearded kind is chestnut on the back, lighter beneath, and covered with scattered black spots : it grows to 20 inches in length. The four-bearded kind has no spots, and has not been found above 14 inches in length. The five-bearded kind is also without spots, and reaches 18 inches.

Habitat. — The three-bearded kind is common in the Mediterranean and extends to Norway, the five-bearded kind ranges from Portugal to Iceland, and the four-bearded from the British Isles to the Arctic Ocean.

Food.—They feed on crustaceans and small fish, and hunt only at night, remaining concealed in holes or under stones in the daytime. The anterior dorsal fin is very narrow, and is frequently kept in a state of rapid vibration in the living fish : the meaning or use of this curious movement is not known.

The buoyant eggs of the five-bearded rockling were studied by George Brook in his private aquarium in 1884. They measure ·7 mm. in diameter (not quite $\frac{3}{100}$ inch). They have a simple yolk and a single oil globule, although when first shed there are often three or four oil globules which soon afterwards run together into one.

The larvæ hatched out $5\frac{1}{2}$ to 6 days after fertilisation, at temperatures from 55° to 62°. They were only 2·25 mm. long ($\frac{9}{100}$ inch). The oil-globule is at the hinder end of the yolk-sac ; the fin-membrane is unusually narrow. The black pigment forms two bands or patches on the tail, as in the larva of the hake.

The later stages of the rocklings are very abundant at the surface of the sea, in summer, but it is difficult to distinguish the different species when very young, in fact until the barbels appear. They are most abundant in May and June, and form largely the food of the mackerel at that season. They have been studied at Plymouth and St. Andrews. The chief peculiarity is the great length of the pelvic fins, which reach back behind the vent and are of a deep black colour on their outer halves. These fins develop very early and are seen in little fish only 6 or 7 mm. long ($\frac{6}{25}$ or $\frac{7}{25}$ inch) when the rays in the dorsal and ventral fins have only just developed. The peculiar front dorsal is not visible. At this stage the skin and body are somewhat transparent, not silvery, and there is black pigment on the back. The breast-fins are short and rounded. In specimens from $\frac{2}{5}$ to 1 inch in length can be traced the gradual development of the silvery livery in the skin, of the front dorsal fin, and the gradual reduction of the long throat fins. Fig. 138 represents a specimen a little more than $\frac{2}{5}$ inch long. Above 1 inch in length, up to $1\frac{1}{2}$ inches the fish remains

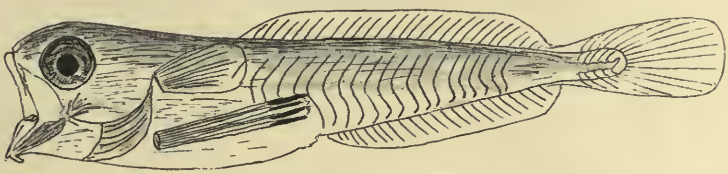

FIG. 138.—Young of the Three-Bearded Rockling in the surface-swimming condition, a little more than $\frac{2}{5}$ inch long.

brilliantly silvery and swims at the surface of the sea, and the barbels begin to appear on the snout.

In calms during May and June, off Plymouth immense numbers of these little fish have been seen from the deck of a mackerel boat. It usually happens at the same time that the surface of the sea is covered everywhere with great quantities of minute round grains, which are living things of low organisation called *Noctiluca*. These are transparent when seen singly, but are in places collected in vast numbers into a thick scum of a salmon-pink colour, which floats in patches and streaks; this scum has a peculiar, not very pleasant, odour. The substance is wrongly supposed by the fishermen to be the spawn of the mackerel. This *Noctiluca* is one of the living things in the sea which gives out light in the dark, and the sight from the bow of a mackerel boat going slowly through the water before a gentle breeze is one of the most curious and beautiful in nature. The little rocklings, or mackerel midges as they are called, dart away from the boat's advancing cutwater through the teeming *Noctiluca*, making lines of light in their tracks, so that it almost seems as though the bows of the boat were constantly giving out rays of light, or as though the vessel were sailing through an enchanted sea.

After the rocklings grow to 1½ inches long they begin to lose their brilliant, silvery dress, and become dull brown. Then they leave the surface of the sea, and are found hiding away under stones on the shore, between tide-marks, or on the bottom in shallow water. The spots of the three-bearded kind do not appear until it is several inches in length.

The Tusk, or Torsk (*Brosmius brosme*).

Distinguishing Characters.—Body cylindrical. The skin is thick and tough, over the fins as well as the body; the vent is rather far back, the ventral fin commencing beneath about the thirty-fifth dorsal ray. Scales minute. Colour on the back greyish, tinged with yellow, which colour is more pronounced on the margins of the fins and gives the fish a very characteristic appearance. Usual length about 18 inches, but the fish grows to over 3 feet.

Habitat.—From Spitzbergen to the latitude of Grimsby, abundant in the Shetlands and Faroe Islands, also on the American coast as far south as Cape Cod. Its range extends to very deep water.

Food.—Chiefly crustaceans and smaller fish.

Breeding.—Of the number examined for Dr. Fulton thirty-nine were females, thirty-five males; and he calculated the number of eggs in a specimen 34 inches long, 15 lbs. 5½ oz. in weight, at 2,283,000. Ripe females were only observed at Peterhead and Lerwick in May and June. In the endeavours to procure fertilised eggs it was noticed that the testes or soft roes were very small in comparison with the ovaries or hard roes. This case resembles somewhat that of the sole. Mr. Duthie the Assistant Fishery Officer at Lerwick, informed Dr. Fulton that the males landed were all immature, but when advised to squeeze the testes in sea-water containing the eggs, he did so, and fertilisation was effected. The soft roes were only 2 to 3 inches long in males of good size, and had the form of a frilled riband as in other fish of the cod family.

The fertilised eggs were sent alive from Lerwick to St. Andrews. They were 1·3 mm. in diameter (over $\frac{1}{20}$ inch), very nearly as large as those of the cod; but there was a single large oil globule of a pale red colour. The space between the egg-membrane and the yolk is small.

The larvæ hatched out on the ninth day, and were about 4 mm long ($\frac{4}{25}$ inch). The oil globule was at the hinder end of the yolk. The black pigment specks were absent from the yolk-sac and fin-membrane as usual in this family, and formed five bands on the body, one on the head, one near the vent, and three on the tail. The coloured pigment is greenish-yellow, and extends on to the yolk-sac and fin-membrane. The larvæ lived in the aquarium for a week, at the end of which time only a trace of the yolk remained, and the mouth and jaws were developed. Little change had taken place in the arrangement of the pigment.

The Sand-eels.

The sand-eels, although usually placed in a different family, are in many respects similar to the fishes of the cod family. They are distinguished by the following peculiarities:—The vent is situated behind the middle of the body, so that the ventral fin is short; there are no throat fins; the dorsal fin is single and extends along nearly the whole length of the back; the tail fin is separate as in the cod-family; the gill-openings are wide, and the lower jaw projects into a spoon-shaped process beyond the upper. This projection of the lower jaw is the instrument by which the fishes burrow into the sand.

There are two kinds on the British and Irish shores, the larger and the smaller or lesser sand-eel. The larger grows to 12 inches in length, the smaller to 7 inches. They are so much alike that it is very difficult to distinguish one kind from the other, but there seems to be no doubt whatever of their independence. The most conspicuous differences are the following:—In the larger kind the projection of the lower jaw is greater; there are two strong teeth in the roof of the mouth, on the bone called the vomer; and the commencement of the dorsal fin is behind the hinder extremity of the pectoral or breast fin. In the smaller kind the two teeth in the roof of the mouth are absent, and the commencement of the dorsal fin is so far forward that the pectoral extends behind it by one-third of its own length. Both kinds are rare in the Mediterranean, where a third species occurs, but extend all along the European shores to the Arctic Ocean. They are not found on the American side, where other species of sand-eel take their place.

Sand-eels feed on small sprats as well as on the young of their own kind, but it seems likely that their food consists partly also of small crustacea.

Breeding.—The spawning of the lesser sand-eel has been investigated successfully in Scotland, but a complete description of the eggs and their development has not been supplied. This species was found to be spawning in June and July, especially in the latter month, at the mouth of the Tyne, in Haddingtonshire. The spawning fish were only obtained from the sand at or below the low water-mark of spring tides, so that the eggs are not left long out of water, although when not spawning the fish are often found buried far above low water-mark. The eggs were artificially fertilised and found to be globular and slightly adhesive. Under the natural conditions they attach themselves to the grains of sand at the surface of the ground and there develop. The attachment is not very firm, and the egg-membrane is easily burst. The egg of the larger species when ripe but not fertilised was ·7 mm. in breadth, the yolk was granular, and there was a large single oil-globule of a green colour. In the smaller sand-eel the perfectly ripe eggs have not been described, but are presumably similar.

The development of the eggs of the lesser sand-eel occupied ten days in July, and the larvæ when hatched were 3 mm. to 3·5 mm. in length ($\frac{12}{100}$ to $\frac{14}{100}$ inch, *i.e.* less than $\frac{3}{20}$ inch). The absorption of the yolk also occupied ten days. No figures of the developing eggs or newly-hatched larvæ have been published.

Certain very slender larvæ, 5 to 6 mm. long ($\frac{1}{5}$ inch), obtained regularly in the bottom tow-nets in March, at St. Andrews, are identified as those of the sand-eel. There is a remnant of yolk in these, and the vent is in the middle of the body. Larvæ of the same length are taken in August. Attempts have been made to explain these facts : it would appear either that the two species have different spawning seasons, one in January and February, the other in June and July, or that the same species spawns twice in each year, or that the larvæ taken in March were hatched in the previous autumn, the spawning period extending for some time beyond July. The last supposition, which seems to me the most improbable, is the one favoured by the naturalist who specially studied the sand-eel at Dunbar. The fact that specimens of the greater sand-eel which were obtained at St. Andrews in May, appeared to be very nearly ripe and contained some ripe eggs, is opposed to the supposition that this species spawns in autumn or winter.

THE RED MULLET FAMILY

THE fishes of this family are all very similar to one another and to our red mullet. They have a rather round body, with large thin scales, which are firmly attached to the skin. There are two dorsal fins which are both short, the first spiny, the second soft, and a ventral fin below the latter. The pelvic fins are directly beneath the breast-fins. The head has a front surface sloping down to the flat under surface, and the jaws and mouth are at the lower part. Beneath the chin are two long stiff barbels, which can be thrust forward and moved about or laid back in the groove between the sides of the lower jaw. Red mullets occur chiefly in tropical seas, and none are large. They live in the neighbourhood of the coasts, on the bottom.

The Red Mullet (*Mullus surmulletus*, and *barbatus*).

Besides the characters given above it is necessary to mention the teeth and the colour. There are two rows of rather blunt teeth in the lower jaw, none in the upper ; none on the tongue, but rounded ones on the palate. In colour two forms are distinguished and it has not yet been finally decided whether these are different kinds or varieties. It seems certain that they are not different sexes. The one is the plain red mullet, the other the surmullet or striped mullet, which has a beautiful red colour on the back and sides, and also three to five bright yellow bands passing along the sides from the head to the tail. The Italian naturalist, Raffaele, at Naples, states that the striped fish bred by themselves in a tank of the aquarium, and that the eggs and young of the other kind were smaller. It appears, therefore, that the two forms are quite distinct. Largest size, 14 to 17 inches in length.

Habitat.—From the Canary Isles to Norway, including the Mediterranean. In the British Isles it is rarely taken in numbers, except on the south and west coasts of England. The plain form seems to belong to more southern regions, and is said to be the commoner in the Mediterranean. Mr. Dunn at Mevagissey has never seen one, and all those that I have seen at Plymouth have been of the striped kind.

Food.—In the aquarium at Plymouth, where they live for a long time and thrive, they are especially fond of shrimps, but will eat also molluscs and worms. They use their stiff barbels to rake in the gravel and sand at the bottom, and so discover shrimps that bury themselves, or worms. Even dead food they feel with the barbels before biting. They have the habit of rising from the bottom in a shoal to swim in mid-water and then settling down again and immediately beginning to rake the ground: in these actions they remind one of a flock of birds. It is curious to see how the red colour becomes darker when they rise from the ground and pales away when they return to it. The red colour is made more intense by removing the scales when the fish are first caught, and the fishermen usually perform this operation in order to improve the appearance of the fish in the market.

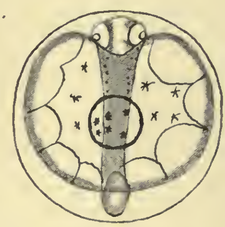

FIG. 139.—Egg of the Striped Red Mullet; after Raffaele.

Breeding.—The spawn has not been studied in this country, but Raffaele studied it at Naples, where it was shed by specimens living in a tank of the aquarium. The eggs are of the buoyant transparent kind. That of the striped mullet is ·93 mm. or not quite $\frac{1}{25}$ inch in breadth, globular in shape, and the yolk has a single oil globule. But the yolk is not simple: there is a layer of large separate masses on the outside, as in the case of the sole and certain other fishes (Fig. 139.) The spawning took place from May to August.

The larva hatched out in three or four days. It has one curious peculiarity, namely that the yolk-sac projects forwards beyond the front of the head, and the oil globule is placed at the extreme end of the projecting portion (Fig. 140.) There are black pigment specks on the body of the larva, none on the fin-membrane. The yolk was absorbed and the mouth open when the larva was seven days old.

The young at later stages are captured at Naples in June, July, and August: they are about an inch long and are already provided with the barbels. They differ from the adults in being

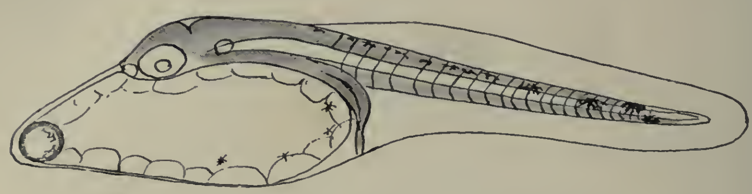

FIG. 140.—Larva of the Red Mullet; after Raffaele.

more slender, and being completely silvery. Later in the year they are found in a more developed condition, red spots commencing to appear.

Young mullet, probably a year old and about 3 inches long, have been taken in seines in Plymouth Sound or its estuaries, in summer. Like many other fish they retire from the coasts in winter and approach them in summer, when they are often taken in seines both on the coast and in estuaries.

THE SEA BREAMS

THESE fishes have a deep plump body, large scales, and a single dorsal fin of which the front part is supported by strong spines while the hinder part has soft fin-rays. There is a ventral fin with three spines and a number of soft rays, the soft part being opposite to that of the dorsal. The pelvic fins are beneath the breast-fins. There are usually sharp cutting or pointed teeth in the front of the jaws, and rounded grinding (molar) teeth at the sides. There are no teeth on the palate. The colour is usually red on the back, silvery on the sides. They are coast fishes of the tropical and temperate regions, none extending to the Arctic or Antarctic seas. They are of very moderate size with few exceptions.

A number of these fishes are taken occasionally on the British coasts, especially on the south and south-west coasts of England and Ireland, but only one of them is at all abundant, namely the common sea bream (*Pagellus centrodontus*). It is distinguished by the possession of molar teeth at the sides of the jaws and the absence of enlarged canine teeth. It is of an orange-scarlet colour above, somewhat silvery on the sides. There is a large black spot on the shoulder, just behind the upper corner of the gill-cover. The breast fin is long, reaching beyond the vent.

This fish occurs in the Mediterranean and extends from thence to Norway; it is taken somewhat frequently round all the coasts of Britain and Ireland, but is only sufficiently plentiful to be of commercial importance on the south and south-west coasts of England and Ireland.

At Plymouth I have found various marine animals in the stomachs of bream, but most abundantly echinoderms, namely, brittle-stars and sand-stars and holothurians or sea-cucumbers :

I also once found a hermit crab with its companion anemone on its shell, zoophytes and sea-weed (*Ulva*).

Breeding and Spawn.—The particulars of the proportions of the sexes and of the spawning period of this fish have not been examined. Raffaele found at Naples that the eggs of *Pagellus erythrinus*, a species closely allied to the common bream and also occurring on the south coast of England, were of the buoyant kind, and that two other species of the family had eggs of this kind. These buoyant eggs floated separately, and were of the type with a simple undivided yolk and a single large oil globule. There can be little doubt, if any, that the eggs of the common bream are of the same kind.

It seems as if it would not be difficult to trace out the growth of these fish at Plymouth with some certainty, as individuals of particular sizes occur in numbers at certain times of the year. But this has not yet been done. All that I can say is the following. The young, known as "chad" and about 6 or 7 inches long, are abundant at the mouth of Plymouth Sound in August and September, and these are probably just over a year old, and immature. I found fish of a younger stage, only about 2 or 3 inches long, in the produce of sprat seines in the Hamoaze in September, and think that these were hatched the same year, their age being something less than six months.

Like most southern fish on the English coasts bream are seldom taken in winter, retiring at that season to a greater distance from land or to more southern regions.

THE MACKEREL OR TUNNY FAMILY

THE fishes of this family have two dorsal fins, the first spiny the second soft ; and one ventral fin placed under the second dorsal. Behind each of these two is a row of small finlets. The pelvic fins are directly below the pectoral. The tail fin is deeply forked. The mouth is large and the jaws strong, but the teeth are small and sharp. The scales are small and without spines, in the tunnies confined to distinctly defined areas on the front part of the body, forming a corselet. The gill-openings are wide. The sides of the tail are sometimes keeled. In some of the tunnies the pectoral fins when closed fit into depressions of the skin, and thus lie level with the surrounding surface.

These fishes are extremely active, migratory, and predaceous. They swim in shoals and seize their prey with great voracity, and hunt merely by sight. They pursue other surface and mid-water fishes, and snap at anything moving through the water, especially if it is silvery like a small surface fish. The different kinds are of very different sizes, from the mackerel not exceeding 18 inches long and 2½ lbs. in weight to the huge tunny sometimes reaching nearly 10 cwt. These fishes are not confined to the neighbourhood of the coasts, although the mackerel is a coast fish, the tunnies ranging through the open oceans. They belong to the tropical and temperate zones, none of them occurring in the Arctic or Antarctic Ocean.

The following are the species found in British waters, with the chief peculiarities which distinguish them from one another.

I. Species of small size in which the two dorsal fins are widely separated ; the corselet is not distinctly defined ; and there is no keel in the middle of the side of the root of the tail.

1. **The Mackerel.**—Air-bladder absent, no sign of a corselet.
2. **The Spanish Mackerel.**—Air-bladder present, a rudimentary corselet of somewhat enlarged scales below the pectoral fin ; eye larger than in the common mackerel.

II. Species of small size with two dorsal fins widely separated ; a corselet on the breast region ; and a keel in the middle of the side of the root of the tail.

3. **The Plain Bonito.**

III. Species of large size in which the first dorsal reaches to the beginning of the second ; the corselet very distinct, and the central keel on the root of the tail well developed.

4. **The Short-finned** or **Common Tunny.**—Corselet distinct ; breast-fin not reaching back to the commencement of the second dorsal.
5. **The Long-finned Tunny** or **Germon.**—Corselet obscure ; breast-fin reaching behind the end of the second dorsal.
6. **The Bonito.**—Breast-fin quite short ; corselet larger than in either of the previous two ; four or five long curved blue stripes passing along the sides and belly, bending upwards behind.
7. **The Pelamid** or **Belted Bonito.**—Corselet much smaller than in the last ; broad bands passing straight down from the back, narrow bands slanting across them downwards and forwards.

The Spanish mackerel is commoner in the south, *i.e.* in the Mediterranean and at Madeira than on the British coasts, and as no practical importance belongs to its history or that of the tunnies in this country, only the common mackerel will be here considered separately. The Remora or sucking fish is placed in the family but has seldom been taken in British seas.

The Mackerel (*Scomber scomber*).

Distinguishing Characters.—Eleven to fourteen spines in the first dorsal fin, which commences a little behind the breast fin.

Five or six finlets behind the second dorsal and the ventral. Scales minute, almost undistinguishable on the sides and belly. A single row of sharp teeth in the jaws, and others on the tongue and roof of the mouth. A slight keel at the base of each lobe of the tail, but none in the centre of the root of the tail. Eyes with transparent upright fixed lids in front and behind. A number of wavy black bands pass down from the mid-dorsal line: between them the colour is deep green: the sides and belly are brilliantly silvery with iridescent reflections. The shape of the body is somewhat slender, sharp at both ends, somewhat narrow from side to side.

Varieties are seen in which there are small black spots or irregular scribbled lines, instead of the usual wavy bands.

Habitat.—From the south of Norway to the Canary Isles, and throughout the Mediterranean. In the British Isles, most abundant in the Channel and northward to Norfolk, but they occur also to some extent along the east coast of Britain to the Orkneys: also in the Irish Sea, and on the south and south-west coasts of Ireland.

Food.—The mackerel is able to live on minute surface creatures, especially crustacea, when small fish are not available. It appears to feed at these times like herring or pilchard, straining the swarms of small creatures through the gill rakers, which are as well developed as in the herring family. Thus at Plymouth in May I found only the minute crustacea called copepods in some stomachs, in some a quantity of the green slimy vegetable matter, which was then abundant in the sea, and amongst it copepods and buoyant fish eggs. In August I found small sprats, and in a considerable number examined in November, only small pilchards between 3 and 4 inches long. The mackerel enter Plymouth Sound and such bays to feed on the young sprats in July and August.

Breeding.—The number of eggs in a single female has been calculated to be from 430,000 to 540,000 in specimens 18 to 20 ounces in weight.

Sars first described the buoyant eggs of the mackerel in 1865. I studied them at the Plymouth Laboratory in 1888. In the latter neighbourhood spawning takes place from the end of May to the latter part of July, and the period seems to be distinctly limited within these times. The spawning fish are found from

14 to 50 or more miles from the coast. Ripe males are taken on hooks, but not the ripe females, which are caught in nets. The stripping and fertilisation of the eggs are extremely easy. The temperature at the surface of the sea at the spawning period was about 54°, and its density 1·0269. The mackerel ova although buoyant in the open sea water where they are naturally shed, are heavier than those of the lemon dab and other fishes, and sink in water in which the latter float.

FIG. 141.—The egg of the Mackerel, alive and magnified.

The egg (Fig. 141), is globular and transparent, the yolk is simple but has a single large oil-globule. The breadth of the egg is 1·22 mm. (not quite $\frac{1}{20}$ inch, more exactly $\frac{48}{1000}$ inch). The eggs hatched on the 6th day at the temperature of 68°.

The newly hatched larva (Fig. 142) is 4·23 mm. long (or not quite $\frac{1}{5}$ inch). The mouth is not open; the oil-globule is at the hinder end of the yolk-sac, and the end of the intestine is just behind the latter. The pigment consists of black and greenish-yellow specks, present on the body and yolk-sac but absent from the fin-membrane. The larvæ were not reared in confinement to a greater age than four days (Fig. 143), when the yolk was very nearly absorbed, and

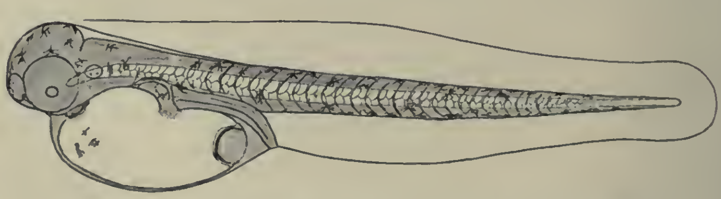

FIG. 142.—Larva of the Mackerel, newly hatched, alive and magnified.

the mouth and jaws were developed, but the formation of the fin-rays had not commenced. Pigment was still absent from the fin-membrane. The later stages and transformation of the mackerel do not appear to have been studied.

Growth and History of the Young.—I did not procure any of the young of the year while at Plymouth. The smallest mackerel

I examined were taken in anchovy nets in November, 1891, between the Sound and the Eddystone. These were 6 inches to 8·3 inches long, and I consider them all to be too large to be derived from the previous spawning, and to be therefore in their second year. They weighed from less than an ounce to over two ounces. A few specimens taken in June on whiffing lines measured 8·7 to 9·3 inches, and these also might be a year old.

The smallest ripe specimens I have examined were 11·6 to 12·9 inches long, weighing 7¼ to 9 ounces, the large ripe specimens being 16 or 17 inches long. We may consider the smaller specimens to be two years old, and the others older.

The young fish do not seem to enter bays or estuaries commonly in large numbers, although I found a few yearling mackerel in the produce of the ground seine in the Hamoaze in September. The young of the year, about 3 inches long, have

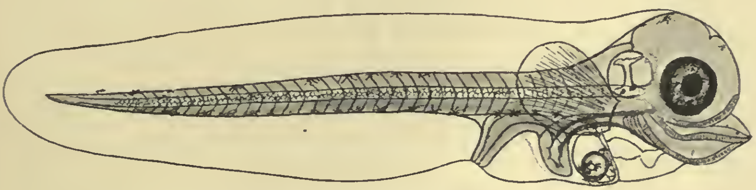

FIG. 143.—Larva of the Mackerel, four days old, alive and magnified.

been observed by Mr. Dunn at Mevagissey, in August and September, but I have never seen or heard of any of that size in Plymouth Sound. At present I am inclined to think that the young in their first half-year remain for the most part out in the open sea.

Migrations.—At Plymouth there is no month in the year in which mackerel are not taken, but they are scarcest in December and January. This is presumably the time when the fish are farthest from the coast, feeding in the more distant water where the temperature is higher. The few caught in those months in 1889–90 were taken 15 to 40 miles south of Plymouth. In February they become more abundant, the largest catches being 4,000 to 5,000, the fish still a long way off, 20 to 30 miles from Start Point. In March and April the fish are still a long way off, at least 30 miles from the Sound in March, 20 miles in

April. In May, however, the fish approach the land while spawning, being taken at the end of the month only a mile or so outside the Breakwater. In June they remain inshore, but these are the smaller fish, and much larger fish are caught off Ushant and the Scilly Islands. At this time fishing by hooks commences. In July and August mackerel enter Plymouth Sound, where they are taken by whiffing lines, and in good years by seine. After the beginning of September they leave the Sound, and are caught a few miles south of the Eddystone. In October and November they are caught from four miles south of the Eddystone, to 20 or 30 miles south of Start Point. Off the coasts of Norfolk and Suffolk there is a valuable drift-net fishery for mackerel, which is carried on in May and June, and also from the 1st September to the middle of November. I do not know why they should be absent in July and August. It seems probable, however, that these fish only visit this part of the North Sea in summer, that they spawn there in May and June, and that they retire to the Channel in the latter part of November.

Along the east coast of Britain north of Norfolk very few mackerel are taken, only a few hundreds being taken in the herring nets in summer. On the west coast of Scotland they are more plentiful. On the west coast of England they are taken regularly in summer in some abundance ; at the Isle of Man the fishery lasts from May to September. In Ireland the principal mackerel fishery is in the south-west, but they are taken in summer all along the west coast.

Mackerel also regularly appear on the south-west coast of Norway, in the Skagerack, and on the west coast of Sweden in May, and give rise to a considerable fishery.

It is a common belief among fishermen that mackerel are blind at the beginning of the year, having a cloudy film over the eyes which obstructs their vision, and which disappears in summer. In support of this belief it is pointed out that they only take a bait in summer. I have never seen anything in the condition of the eyes to warrant this belief, although I have examined plenty of mackerel at all seasons of the year. The two fleshy transparent upright lids are always present ; there is an opening between them where the eye is uncovered. But I have never seen any cloudiness in these lids, nor anything peculiar in the appearance of the eyes in winter or spring. It is a fact that fishing for mackerel with hook and bait is usually only carried on in summer, but this is apparently sufficiently explained by the fact that this kind of fishing, usually called "whiffing," is practised by small long-shore boats which do not go far from shore, and the mackerel only approach close to the land in summer. The fish are more readily taken on hooks after the end of June, because in the spawning season they take less food, especially the females, which for a time cease to feed altogether.

THE FAMILY OF THE SCADS, OR HORSE-MACKERELS

THIS is a large family of fishes belonging to tropical and temperate seas, and more abundant in the tropics. The fishes included in it show considerable differences from one another, and it is not easy to mention peculiarities which are common to them all. The body is always more or less narrow from side to side, sometimes thin and of great vertical height; the eyes are on the sides of the head. The spiny front dorsal fin is shorter at the base than the second, and in many species reduced to short separate spines. The lateral line is in some armed with bony plates. There are sometimes separate finlets behind the dorsal and ventral fins as in the mackerel.

The only fish of this family which is common in British seas is the scad or common horse-mackerel, but the pilot-fish and others have been taken occasionally on our coasts.

The eggs are not well known, but are probably buoyant in the majority of species, if not in all. One species is the skip-jack or blue-fish of the coasts of the United States, and the eggs believed to belong to this fish have a layer of yolk segments and a single oil globule like those of the red mullet.

The Scad, or Horse-Mackerel.

Distinguishing Characters.—This fish has a front dorsal fin of eight spines, a long soft second dorsal and ventral; there are two spines in front of and separate from the ventral. The most marked peculiarity is the lateral line, armed throughout its length with plate-like bony scales, which towards the hinder end of the fish are keeled. The scales present on the head and rest of the body are very small. The colour is a dark bluish on the back, silvery on the sides and belly. The tail is forked. The greatest length attained is 20 inches.

Habitat.—This fish is found almost all over the world, extending from the Mediterranean northwards to Denmark, southwards to the Cape of Good Hope, and found also in China, Australia, and Chili; it appears to be absent from the western shores of the Atlantic. In Britain and Ireland it is found all round the coasts, but becomes scarce in the extreme north. In food and habits it closely resembles the mackerel.

Breeding.—The fertilised eggs have not been obtained and examined. In May, 1894, Mr. Holt obtained at Grimsby some apparently ripe females from the North Sea, but they had been caught the day before he received them. The eggs were quite transparent, and floated in water at Cleethorpes, which was not so salt as that of the sea. In breadth they were 1·03 to 1·09 mm. or $\frac{1}{25}$ inch. There was either a single oil globule or two or three which united afterwards. The yolk was divided throughout its substance into large masses, and it was remarkable that these projected at the surface, so that the surface of the yolk was not smooth and even as it usually is. Artificial fertilisation was not successful, and the eggs did not live in sea-water more than forty-eight hours. It seems very probable that the peculiarities of these eggs, different from any known in others, are due partly to the fact that they were not perfectly ripe, partly to the fact that the females from which they came had been dead for twenty-four hours. It will probably be found that the eggs of the scad when fertilised are like those which are believed on good evidence to belong to the American blue-fish, and that the yolk-masses, as described by Mr. Holt, simply show an unnatural or imperfectly developed condition of the outer layer of yolk segments which is natural in the fertilised eggs.

Although I have not examined the eggs at Plymouth, I have obtained the young in the tow-net at the surface in August and September. I took four specimens in all, from 1 inch to 2 inches in length, from two to five miles off the coast. These were fish which had passed through their transformations and developed the characters of the fully developed scad; and as spawning appears to take place in May and June their age may be reckoned at from two to four months.

THE JOHN DORY FAMILY

THIS family is rather closely allied to that of the horse-mackerels. Its chief characteristics are that the body is high and narrow from side to side; that the front dorsal fin consists of a few strong spines which are elongated; that the second dorsal is not completely separate, and like the ventral is rounded behind. The mouth is constructed in a curious way so that when it is opened the upper jaw is thrust far forward, and the whole mouth forms a kind of long tube. The tail is rounded at its hinder edge, while in the horse-mackerels it is more or less forked.

The fishes of this family inhabit the seas of the temperate regions. They are slow swimmers, and feed chiefly on smaller fish. So far as known their eggs are buoyant. Two species are common in British waters:—

1. **The Boar-fish** or **Cuckoo.**—Orange-red in colour; scales small but with spines making the skin very rough. Membrane of the first dorsal not produced into filaments.
2. **The John Dory.**—Scales small, and not spiny; skin smooth. Membrane of the first dorsal prolonged into filaments. Colour olive or brownish with yellow bands; in the centre of each side a round black spot surrounded by a yellow ring.

The Boar-fish, or Cuckoo (*Capros aper*).

Distinguishing Characters.—Besides those above mentioned, the teeth in the jaws are minute; there is a row of small spines on the gill-cover; there is a roughened bony ridge along the bases of the second dorsal and ventral fins, but no spines. The ventral fin is similar to the second dorsal, and there is a small front ventral fin consisting of three small spines. The first ray of the throat fin is thick, long, and rough. It is a small fish, not exceeding 7 inches in length.

The fish is found in the Mediterranean, and on the Atlantic coast from Madeira to England. It approaches the coast in summer from May to October, and off Devon and Cornwall is very abundant; north of the English Channel it has been only occasionally taken. It swims near the bottom and hundreds are taken by the Plymouth trawlers in summer time in every haul of the trawl. The limits of the spawning period I do not know, but I found numbers of ripe specimens on August 15th, 1887, on board a trawler to the east of the Eddystone, and I fertilised some of the eggs, which were buoyant and transparent. The egg is ·97 to 1·5 mm. in breadth or about $\frac{1}{25}$ inch, and is globular. The yolk is simple and undivided, and there is a large single oil globule. None of the eggs were hatched and the larva and its transformations have not been traced out.

The John Dory (*Zeus faber*).

Distinguishing Characters.—Along the base of the dorsal fins on each side is a row of spines, those at the base of the second dorsal being double; similar spines at the base of the hinder ventral fin. The front ventral fin consists of four strong, thick, spiny rays. The throat-fin is a little in front of the breast-fin, and is nearly as long as the first dorsal, filaments included. The mouth is large and much protruded when open. The largest specimen was 22½ inches long, and 18 lbs. weight.

Habitat.—Like the boar fish, the dory is a fish of the Mediterranean, and is spread on the Atlantic coast from Madeira to Norway. It is common in the English Channel and Bristol Channel, where it has considerable importance in the market, and occurs all round the coast of Ireland; but on the east coast of Britain and in the North Sea, it is rare. In the Irish Survey it was not taken at greater depths than 40 fathoms.

The dory feeds entirely on fish. At Plymouth from December to March, I found only pilchards and herring in their stomachs, when the half digested remains were recognisable at all. During the Irish Survey only sand-eels and herrings were recognised. In the aquarium at Plymouth, I have noticed that the dory has a peculiar and interesting method of securing its prey. It does not overtake it by superior speed like the mackerel, or lie in wait for it like the angler, but stalks it and approaches it by stealth. It is able to do this in consequence of the extreme thinness of its body, and the peculiar movement of its hinder dorsal and ventral fins. The dory places itself end on towards the fish it desires to devour, and in this position it is evident that it excites no alarm on the part of its prey. The appearance of the dory seen in this way is a mere line in the water, to which no particular significance can be attached. I have not particularly noticed the effect of the ribbons of membrane, which project from the dorsal fin. But I have observed that the movements of the dory are very gradual, except in turning: it alters the position of its body by a turn of the tail or side fins, and then slowly swims forward by vibrating the second dorsal and ventral, a movement which causes very slight disturbance of the water. The whole appearance of the dory in these actions is suggestive of suppressed excitement, his eyes being fixed on his prey. I do not recollect seeing him actually swallow another fish, but have no doubt that he gets near enough to a sprat for example, without alarming it, to seize it by the sudden elongation of his curious jaws.

Breeding.—In the Irish Survey ripe females were found in July and August, and one spent in June. At Plymouth I found them ripe in August. This is enough evidence to indicate the spawning season, but unfortunately no one has examined the eggs. In all probability they are of the same type as those of the boar-fish above described. The larvæ and their transformation also are at present unknown, but considerable evidence has been collected concerning the growth of the young. In summer, from June to September, specimens from a little less than 5 inches to 7·3 inches in length are taken in considerable numbers by the trawlers at Plymouth, at depths from 5 fathoms to 35 fathoms. It is clear that these cannot be less than a year old, and there is no reason to suppose that they are more. Smaller specimens are taken in autumn and winter. The only one I have recorded was 1·7 inch, taken in Cawsand Bay, Plymouth Sound, at the beginning of October. This one I consider to have been about three months old.

In the Irish Survey the smallest ripe male was 11 inches long, the smallest ripe female 15 inches ; but only a small number were obtained.

Migrations.—On the coasts of Devon and Cornwall, the movements of these fish do not appear to take the form of regular migrations. They seem to leave the bays and shallow waters in winter, but at that season are taken by the trawlers at depths of 30 to 40 fathoms. Considering the inactive mode of life of the fish, it is not surprising that it should be taken in the trawl, when swimming near the bottom, but the character of its food shows that it is not specially addicted to the neighbourhood of the bottom, but able to rise to any level : and the fact that it possesses an air-bladder also shows that it can swim in mid-water.

THE GURNARD FAMILY

THIS family includes both the gurnards and the bullheads, the latter being of no commercial importance. The distinguishing characters are that the bones of the head are armed with backward-directed spines ; that there are two dorsal fins and one ventral, the second dorsal and ventral being long and opposite to one another and supported by soft or flexible fin-rays, while the first dorsal has spiny rays, and is shorter than either of the others. The breast-fins are large, the pelvic or hinder pair on the chest beneath them; the hinder edge of the tail-fin is rounded or straight. Scales are well developed and more or less spiny in the gurnards, absent in the bullheads. The body is rather round and plump.

These fishes are always of rather small size, and not powerful or active swimmers. They live on the bottom, near or not far from the coasts, and are found in all seas, arctic, temperate, and tropical. The following are found in British and Irish seas:

I. Species in which the skin is soft and scaleless, and the breast fin in the ordinary condition.

1. **The Miller's Thumb.**—No spine on the opercular bone or above the eye. First dorsal fin narrow, only half as high as the second. Not more than 5 inches long. Lives in fresh water.
2. **Father-lasher,** or **Short-spined** (*Cottus*).—Sea-scorpion. First dorsal fin nearly as high as the second. A spine above the eye, and four principal spines on the gill-cover, the uppermost of which is short and smooth.
3. **Long-spined** (*Cottus*).—Five principal spines on the gill-cover, the uppermost of which is long and rough.
4. **Four-horned** (*Cottus*). — Two pairs of large rough

tubercles on the upper surface of the head, and a row of similar tubercles or two rows along the sides.

II. Gurnards, species in which the head is strongly armoured with bony plates, and has an angular wall-sided shape; spines along the lateral line and along the bases of the dorsal fins. The three lowest rays of the breast fins separate and independently movable, used as fingers.

5. **The Grey Gurnard.**—No spines along the bases of the dorsal fins, spinous points along the lateral line. Grey in colour with white spots.
6. **The Red Gurnard.**—A ridge along the base of the dorsal fins with about twenty-seven spines; scales on the lateral line without spines, but having the form of narrow plates across the line.
7. **The Tub-fish, Tub, Sapphirine Gurnard,** or **Latchet.**—Spines along the base of the dorsals. Pectoral fins much enlarged, reaching behind the commencement of the ventral fin, and coloured with rich blue colour on the hinder surface, which in life is displayed upwards.
8. **The Piper.**—Bones of the head above the upper jaw projecting in two large flat plates, which are toothed along their front edges. Pectoral large as in the tub, but not so broad and not brilliantly coloured.
9. **The Long-finned Gurnard.**—The second spine of the dorsal fin much elongated; a shining silvery band along each side of the body.
10. **The Streaked Gurnard.**—Lateral line with saw-like spines; spines along the bases of the dorsals. Raised ridges passing from the back in a direction slanting forward down the sides.

The habits and development of the sea-scorpions are very different from those of the gurnards, and perhaps it would be more reasonable to consider them as belonging to distinct families. The former are found in very shallow water, being often found above low water-mark, lurking among stones, rocks and sea-weed, and darting out at any prey which comes near them. The eggs are large and adhesive, and are deposited in clumps which adhere to stones or other objects on the bottom. The gurnards on the other hand, live in deeper water, and their eggs are of the transparent buoyant kind.

The four-horned cottus belongs more particularly to the Arctic Ocean and the northern part of the Baltic. It is said to have been taken on the north coast of England and at Weymouth, but neither this nor the fresh water form need be further considered here.

The Bullheads (*Cottus scorpius and C. bubalis*).

The long-spined form is smaller than the other, not exceeding 12 inches in length, and as usually seen only 6 to 9 inches. It is found in the arctic regions and in America, but seems to extend further south than the short-spined form. It is the only species I have found at Plymouth, and is much the commoner species on the west coast of Ireland, while at St. Andrews the short-spined form is commoner. The largest specimen of the sea-scorpion or short-spined form obtained in Britain was 15 inches long, but the same species is said to reach 6 feet in Greenland.

In colour the bullheads are brownish or yellow, with large irregular markings of black and white. Occasionally on the south coast, brilliant red or carmine coloured specimens of the long-spined species are taken. These come always from rather deep water, and I think they live among red sea-weed. The carmine-coloured pigment is present in the ordinary dull and dark-coloured specimens found on the shore, but in these it is much obscured by the large amount of brown or black pigment present. In the carmine specimens, the black is reduced and the carmine colour comes into view. The carmine colour extends all over the back and sides, except where it is relieved by patches of pure chalk-white and black: there are also small yellow marks chiefly on the fins, so that these fish present a very striking and gaudy appearance. It seems possible that the variety is not permanent, but due to the influence of coloured surroundings, that is of the action of coloured light, on the changeable pigment-cells of individuals.

The eggs are deposited in the earlier months of the year, February to April or later. The egg-masses in the smaller form are somewhat larger than a walnut, in the other about as large as a man's fist. They are often found between tide-marks at low water. It is stated that the male guards them, and it is probable that they require the attention of one or other of the parents, to keep a current of water over and through them, but I know of no direct observations in this case. The eggs of the sea-scorpion are $\frac{2}{10}$ inch in breadth, of the other somewhat less. The yolk is made up of minute globules, and is of a red or orange colour in the sea-scorpion, yellow or nearly colourless in the long-spined species. There are several oil globules of various sizes, but during development they unite together into one, which is placed at the front end of the yolk in the hatched larva.

The development occupies some weeks. The clumps can often be found with the larvæ just ready to hatch out from them. These larvæ are much larger, more developed, and more active

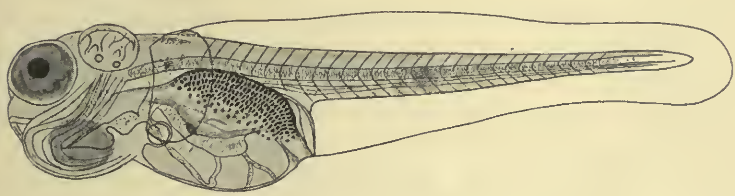

FIG. 144.—Newly hatched larva of the Long-spined Bullhead, alive and magnified.

than any larvæ hatched from buoyant eggs. In fact, in adhesive eggs generally there is a considerably larger quantity of yolk, the development in the egg is more prolonged, and in consequence of this, the fry when first hatched are in a more developed condition. The larva of the sea-scorpion is about 7·5 mm. long or $\frac{3}{10}$ inch, that of the long-spined bullhead (Fig. 144) 5·7 mm., or a little more than $\frac{2}{10}$ inch. The differences in character between the two kinds are very slight. The head is rounded and large, and the mouth and jaws well developed. The abdominal region is very short, and the tail long. As usual in eggs developed at the bottom, red blood is seen coursing in veins over the yolk-sac. The primitive fin-membrane passes from behind the head round the end of the tail, to the hinder end of the yolk-sac, where the intestine opens: this membrane is enlarged at the tail end, and narrower at the root of the tail. But the most characteristic feature in the larva is the mantle of black star-shaped pigment specks in the roof of the belly cavity: the larva being transparent, this pigment is very conspicuous. There are also yellow pigment and a few black specks on the head and yolk-sac, but at first there is none in the tail.

The Gurnards (*Trigla gurnardus, cuculus, hirundo and lyra*).

The differences among these fishes in importance and in history are so slight that nothing would be gained by giving a separate account of each.

Distinguishing Characters.—It should be understood that the bones which cover the surface of the head are the same which are present in the heads of other fishes, but here are thicker and broader, and bare, no soft skin extending over them. The bones of the gill-cover are furnished with strong spines. The three separate rays of the breast fins which form one of the most remarkable peculiarities of these fishes remind one somewhat of the legs of an insect, but are more properly to be compared to our own fingers, since they are part of the divided extremity of limbs which correspond to our own arms. Their use, too, is more that of fingers than of legs, since they are employed, like the barbels of other fishes, to feel the ground and rake over loose stones, in order to discover small crustacea and other animals on which the fish feeds. These fishes have another interesting peculiarity: they utter sounds, resembling faint grunts. These sounds are produced in the air-bladder. That organ is entirely closed, and its walls contain well developed muscles, which by their contraction, drive the air from one part of the bladder to another. In the tub, or latchet, the air-bladder consists of three portions, a larger central chamber and a smaller chamber on each side, communicating with the central chamber at the front end. At the hinder portion of the central chamber there is a partition running in a slanting direction across it, and in the middle of this partition is a round opening. The air is pressed to and fro through this opening, and so the sound is produced.

The use of the sounds is not well understood, no thorough investigation of the question by means of experiments and observations on living fish in aquaria having yet been made. But it seems probable that the fish communicate with one another by these sounds. The sounds are not usually heard by an observer when the fish is in the water, because they do not pass readily, if at all, from the water to the air, but if the fish is taken out of the water they are heard distinctly enough.

The piper is the largest of the species, the tub next, the grey gurnard next, and the red the smallest. The piper reaches a length of 2 feet, and the tub grows nearly as large. The grey gurnard is seldom seen as long as 18 inches, and the red gurnard is usually smaller. In colour all the gurnards except the grey are red or brownish-red on the back and white on the sides: the sides and belly are not brilliant or silvery. The hinder surface of the breast-fin in the sapphirine gurnard, or tub, is blue at the margins and reddish within the margin, while the central part is blue with black blotches.

Habitat.—Gurnards are found in tropical and temperate seas, not extending to the arctic regions. Of the species here considered the grey gurnard is the most northern, extending from the Mediterranean to Norway and the Baltic. It is found all over the North Sea as well as on all the coasts of Britain and Ireland. The red gurnard also extends from the Mediterranean to Norway, but is much less abundant in the North Sea and on the east coast of Scotland than the grey; in fact, it is scarce in the North Sea.

The tub has a range very similiar to that of the red gurnard: it is found on the coast of Norway, and in small numbers on the east coast of Scotland, but is rare in the North Sea except in the southern narrower part and in the Heligoland Bight; it is fairly plentiful on the south coast of England, south and west coasts of Ireland. The piper is still more confined to southern regions, not being taken on the east coasts of England or Scotland, or in Norway. The long-finned gurnard and the streaked gurnard have been taken chiefly on the south coast of England. The greatest depth at which the grey gurnard was taken in the Irish Survey was 80 fathoms, but the piper was taken at 144 fathoms, and the red gurnard has been taken at 165 fathoms.

Food.—In the Irish Survey specimens of all four species were captured and examined. The food in all was varied, crustacea being in greatest proportion. Of the crustacea the chief forms were crabs, especially swimming crabs, and shrimps. Fishes were next in order of frequency, and were usually sand-eels or sprats, though dabs and other flat-fishes were occasionally found. In the piper, besides crustaceans and fish, sand-stars were also found, and molluscs were occasionally present in both piper and tub.

Breeding.—In the grey gurnard, Dr. Fulton found there were 409 females to 100 males, while the females were very slightly larger than the males, the proportion in length being as 108 to 100. The number of eggs in the ovaries at one time was found by computation to be from 192,000 in a specimen 12½ inches long, to 297,000 in a specimen 13½ inches.

In accordance with the superiority of the females in number the spawning period is prolonged. In the Irish Survey ripe female grey gurnard were observed in March, April, May, June, and July. On the east coast of Scotland they have been observed from April to August. I found both the red and the grey kind spawning off Plymouth in April and May.

There is no evidence at present of the preference by gurnards of particular grounds for spawning. They spawn at various depths and distances from shore, in Scotland according to Fulton, both in territorial and extra-territorial waters. The least depth at which ripe females were taken, on the west coast of Ireland was in the case of the red gurnard 13 fathoms, in the case of the grey about 10 fathoms.

The Eggs and their Development.—The eggs of the red and grey gurnards have been studied; those of the tub and piper and the rest have not yet been examined. The eggs have been obtained by artificial fertilisation, and also by tow-nets from the sea. They have been hatched without difficulty in aquaria at Plymouth and at St Andrews. They are of the buoyant transparent kind, and belong to the type with a simple undivided yolk and a single large oil globule. The eggs of the two species resemble one another very closely (Fig. 145). In size those of the grey gurnard are very slightly the smaller, on the average, but in both cases there is considerable variation, those of the grey being from 1·42 to 1·55 mm., those of the red from 1·47 to 1·61 mm. in breadth. (In fractions of an inch $\frac{5}{100}$ to $\frac{6}{100}$ or about $\frac{1}{20}$ is sufficiently exact for most purposes.) In both cases the oil globule when the egg is first shed is brownish-yellow, or copper-coloured, but in the later stages of development the colour gradually disappears. Mr. Holt has observed that there are often two or three oil globules in the eggs as they come from the fish, but they usually unite into one in a very short time.

At Plymouth the eggs of the red gurnard hatched in six days: at a lower temperature at St. Andrews those of the grey took thirteen days to hatch. The newly hatched larva of the red gurnard is 3·7 mm. in length (not quite $\frac{3}{20}$ inch). The intestine ends close behind the yolk-sac, in which the oil globule is at the hinder end. The mouth is not open: the rudiments of the breast-fins are unusually large. The pigment is black and orange, and is present over the body and yolk-sac, and along the edges of the longitudinal fin-membrane.

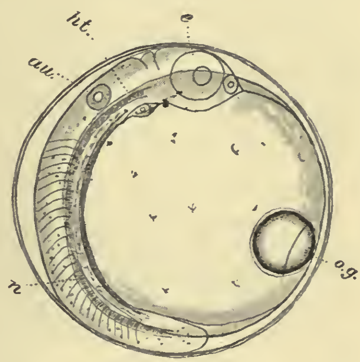

FIG. 145.—Egg of Red Gurnard, alive and magnified.

o.g. oil-globule; *e.* eye; *ht.* heart; *au.* organ of hearing; *n.* notochord, or rudiment of backbone.

The larvæ of the grey gurnard were kept alive in aquaria at St. Andrews by Prof. McIntosh for three weeks after hatching. At the end of this time they were about 6 mm. ($\frac{6}{25}$ inch) long, and the yolk was absorbed. Only fine primitive fin-rays were present in the breast-fins, none in the longitudinal fin-membrane.

A succession of later stages were obtained by the tow-net in St. Andrews Bay at 23 fathoms. They were from 6 mm. upwards in length, and their stomachs contained, as usual in young fishes at these stages, the minute crustacea called copepods. They showed the most interesting changes in the process of transformation to the fully developed fish. At $\frac{3}{5}$ inch in length (Fig. 146) the development of the permanent fins has made considerable progress. The two dorsals, ventral, and caudal are all marked out and provided with primitive fine fin-rays, but the first dorsal is not separate from the second. The breast-fins are of proportionally enormous size, reaching nearly to the base of the tail, and provided with the permanent fin-rays. It is interesting to note that in this stage the three lowest rays are not yet separate, but are connected to the rest of the fin by membrane as in other fishes. The throat-fins, or second pair of side-fins, are present, but shorter and narrower than the breast-fins. This stage was obtained towards the end of August. An older stage, also procured in August in St. Andrews Bay, was 22 mm. long (over $\frac{4}{5}$ inch). It has nearly all the characters of the full grown fish, but is more brilliantly coloured, and the scales and spines are not fully developed. In this stage the three fingers of the breast-fins on each side are separate, except at their bases, and these fins themselves are shorter in proportion to the length of the fish, reaching a little beyond the commencement of the ventral and second dorsal. The spines at the bases of the dorsal fins and along the lateral line were present in specimens 24 mm. long, or very nearly 1 inch.

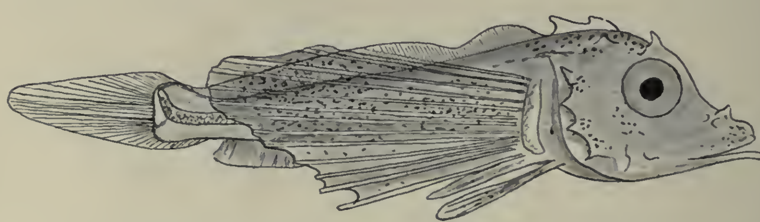

FIG. 146.—Young of Grey Gurnard $\frac{3}{8}$ inch long; after Prince.

Young grey gurnards $2\frac{3}{4}$, 3, $4\frac{3}{4}$, and $6\frac{1}{2}$ inches long were taken at St. Andrews in June, and $4\frac{1}{8}$ to $6\frac{1}{8}$ inches in May. There can be little doubt that these are nearly a year old. During the Irish Survey young grey gurnards of the year, $\frac{1}{4}$ to $\frac{1}{2}$ inch long, were taken at less than 5 fathoms in May, others under 2 inches were taken at depths between 5 and 45 fathoms in August. It appears, therefore, that these early stages are not confined to very shallow water. A large haul of the yearling fish, consisting of 300 specimens, 3 to $7\frac{1}{2}$ inches long, was taken near the Arran Islands at 20 to 25 fathoms in April.

Size at which sexual maturity is attained.—According to the observations made in the Irish Survey the smallest ripe male grey gurnard was 7 inches long, the smallest ripe female $9\frac{1}{2}$ inches. The red gurnard of both sexes were mature at 13 inches. Of the tub or sapphirine gurnard, males were ripe at

12 inches and upwards, but a female at this size was immature. As far as the evidence goes it indicates, as will be seen, that maturity is not attained until the second season after hatching.

Migrations and habits.—We have no evidence at present of any regular migrations of gurnards, except that like many other fishes they appear to come nearer inshore in summer. Couch and other naturalists assert that they sometimes rise to the surface and sport there. In the aquarium at Plymouth and elsewhere it has been observed that they do not live long, being apparently unable to bear confinement. The sapphirine gurnard has the curious habit of spreading out its breast fins with the brilliantly coloured surface uppermost, when it is alarmed, as by the approach of the hand or a stick. The use of this to the fish or the reason of it is not obvious. The piper probably uses its peculiarly armed snout to dig up the gravel and turn over stones, but this habit has not been observed.

GREY MULLETS

THESE fishes are all closely similar. They have an elegantly shaped, somewhat elongated body, rather rounded, covered with smooth-edged scales. There are two short dorsal fins, the front one composed of four spines. The ventral fin is opposite the second dorsal. The pelvic or throat-fin is behind the breast-fin. The tail-fin is large and somewhat forked. The teeth are very feeble or absent. These fish belong to the tropical and temperate shores, and frequent harbours, inlets, and estuaries. They feed largely on the vegetable growths of green or brown colour which form a coating over all objects in shallow water, and they suck gravel, sand, and mud to obtain the same substances; minute molluscs are also found in their stomachs. The latter are provided with a strong gizzard like that of a bird, and the intestine is very long and folded.

The spawn has not been studied in this country, but at Naples Raffaele fertilised artificially the eggs of one species, probably the thin-lipped mullet. They were of the free buoyant kind, about $\frac{1}{25}$ inch in breadth, and having a simple yolk with a single oil globule. The larva was like that of other fishes with buoyant eggs.

As mullet are so frequently found in brackish water, and can be kept in fresh water, the question arises whether all of them spawn in the sea. Concerning species which naturally live in fresh water permanently, there is no doubt that they spawn there, but with regard to brackish water forms like our own they doubtless spawn in the sea, and there is no reliable evidence that they can spawn and develop when confined in fresh water.

There are generally stated to be two British species, one in which the upper lip is thin, and the other in which it is thick. Certain other minute differences exist between them, but at Plymouth all that I have seen belonged to the thick-lipped species. Perhaps the other species is scarce.

The Thick-lipped Grey Mullet (*Mugil chelo*).

There is no lateral line. It reaches sometimes 2 or even 3 feet in length. The colour is silvery-grey, with rows of dark strokes along the sides.

These fish swim in shoals, and sometimes many thousands are enclosed in a large seine at one time.

An advanced larva, believed to belong to this species, was obtained from Mr. Dunn at Mevagissey, in May (Fig. 147). It was 10·5 mm. long, or over $\frac{2}{5}$ inch. The head and jaws were well developed, but there were no fin-rays, except a few commencing in the tail. The breast-fins were large and membranous, and the primitive fin-membrane extended from the

FIG. 147.—Larva of Grey Mullet, a little more than $\frac{2}{5}$ inch long, alive and magnified.

back round the hinder end of the body to the vent. Spawning would therefore seem to commence at the end of April. I obtained others a little more advanced in the middle of May, in Cawsand Bay, Plymouth Sound.

In July and August the young mullet are abundant at the surface off the mouth of Plymouth Sound. These are $\frac{3}{4}$ inch to an inch long. A number of them were reared in the aquarium, being fed on finely-minced marine worms, which they took freely off plates suspended in the water, but their growth was slow: in August of the following year they were only $2\frac{1}{4}$ to 3 inches long. Whether this fairly represents the natural growth in the sea there is no evidence to show, but I should think the average size at one year of age would be somewhat greater under the natural conditions.

THE ANGLER FAMILY

THE fishes of this family, of which only the common angler or fishing frog is British, have a very peculiar organisation. They are without the great development of the tail and body muscles by which the swimming powers usually expected in a fish are produced, but have, on the other hand, a very great development of the head, jaws, belly, and paired fins. But these side-fins being used, not for swimming, but rather as flippers for shuffling along the sea bottom, or for holding on to sea-weeds or other objects, form blunt, fleshy limbs, not broad fan-like paddles. The most characteristic feature is that the first dorsal fin in these fishes is represented by a few long, separate rays, the first of which is usually terminated by a flap of skin, and this ray, which can be raised or lowered, is used as a lure to attract other fish, which the anglers seize with their enormous jaws. The capacious and elastic stomach doubtless indicates that these fishes, like snakes, make a large meal at long intervals, their mode of obtaining food necessarily implying long periods of fasting. The gill-opening is small, and situated below the base of the breast fin. The gills themselves are reduced in number from the four usually present to three-and-a-half, three, or even two-and-a-half. The bones at the base of the breast fin are enlarged, and form a sort of arm ; the rays are very short. The pelvic fins are placed on the throat in front of the breast-fins, and have a similar structure. There is a second dorsal and a ventral fin opposite to one another. The skin is usually provided with projecting lappets or fringes which aid in concealment, one chief necessity of these fishes.

Anglers are found all over the world, and are adapted to an inactive life of concealment, in three different regions, namely the shallow grounds near land, the deep sea, and the surface of the ocean. In the latter case they are only found among floating sea-weed such as the Sargasso, to which they cling by means of their arm-like fins. These forms are narrow from side to side, while the others which live on the bottom are broad and flattened from above downwards. Some of the deep-sea species present a most remarkable peculiarity : at the end of the tentacle on the snout instead of a flag-like membrane is a little fleshy knob which contains a luminous organ, so that they fish with an incandescent lamp as an attraction.

The Angler or Frog-fish (*Lophius piscatorius*).

Distinguishing Characters.—Head large, broader than long ; body short and tapering. Eye small. Mouth very wide, the upper jaw shorter than the lower. Two rows of sharp teeth in each jaw directed backwards and movable, a few on the palate, none on the tongue. The first dorsal fin of six spines, of which the first is on the snout, immediately behind the upper jaw, and ends in a flag-like membrane. Ventral fin shorter than the second dorsal. Numerous spines over the head, and fringed lappets projecting from the skin all round the margin of the body and on the tail. The colour is slaty-brown, with a net-work of darker lines ; lower side white. The usual size is from 2 to 3 feet in length, though specimens are occasionally taken over 6 feet long. At Grimsby it is called the monk-fish, a name which more properly belongs to *Rhina squatina*, a fish of the skate tribe.

Habitat.—The angler is found everywhere on the east side of the Atlantic, from the Shetland Isles to the Mediterranean, and on the west side from Newfoundland to Cape Hatteras. It is abundant in the North Sea, and all round the British and Irish coasts. At Grimsby the flesh of the sides is cut out and sent to market, so that by the fishermen of that port the fish are always brought in, and fetch a certain price.

Food.—A full account of the food and habits of the angler is given in Day's *British Fishes* (vol. i. p. 75). But there is one sentence there which deserves to form the text for some additional remarks :—" Its floating filaments kept in motion by the tide decoy other fish, and the angler's tendril is no sooner touched than the game is caught." Now, although the tentacle of the fish naturally suggests a fisherman's line with a bait on the end, it is by no means certain that there is anything particularly attractive to other fishes in this tentacle or its membrane. But, on the other hand, it is certain that the concealment of the fish, on account of its colour and appearance, is very perfect ; it cannot be distinguished from a boulder or a piece of rock with bits of seaweed and other growths attached to it. Mr. Saville Kent stated, from observations in the Brighton aquarium, that when the angler saw fish in its neighbourhood it became excited and agitated its tentacle, the "glittering piece of skin" at the end of which served as a lure. I have seen nothing that could be described as glittering in the appendage of the tentacle: in the dead fish, at least, it is a thin flexible piece of skin of a whitish or light-grey colour, dull and not glistening. At the base there is a black spot on each side of the end of the stalk. The membrane is divided at its further edge into two parts by a deep cleft, and the edge of each part is slightly divided by smaller clefts. The stalk is curved at its outer end, so that the membrane hangs downwards. It is true that anything moving in the water will attract the attention of fishes that hunt by sight. But another and perhaps more important use of the tentacle is indicated by some experiments made during the Irish Survey by Mr. Lane, and mentioned in Mr. Holt's Report (Scientific Proc. Royal Dublin Society, vol. vii. part 4, p. 459). Mr. Lane found that when he touched the top of the erected tentacle with a stick the fish at once snapped with his jaws, so as to catch exactly that part of the stick which had touched his tentacle. This was repeated many times, until the fish was exhausted. It is evident that this automatic and precise mechanism of sensitive nerve and jaw-muscles must be most effective in the capture of the angler's prey. It is a spring-trap of the most certain action, always set, and never betraying its nature. Any fishes swimming near the ground are liable to touch the tentacle of an angler, which cannot be distinguished from the most innocent and insignificant frond of weed or stem of zoophyte, and to touch it is certain and immediate death.

Breeding.—Day mentions that the eggs in a female 4½ feet long were computed to be nearly a million and a half, and that the spawn, according to Baird, the founder of the United States Fish Commission, was a floating sheet of mucus 60 to 100 feet square. An excellent description with figures of this spawn and of the young of the angler (larvæ) was given as long ago as 1882 by Alexander Agassiz in America. According to this account the real dimensions of the sheet of spawn were considerably less, namely, 2 to 3 feet in breadth and from 25 to 30 feet long. The mucus was of a violet-grey colour, and the black pigment of the larvæ gave it a blackish appearance. The eggs were in a single layer. Agassiz found the spawn in the latter part of August. In Scotland the spawn sheets have been found: one stranded on the shore in July, in the Firth of Forth, was 36 feet long and 10 inches wide. Two other specimens were obtained in February.

At Plymouth a sheet of the spawn was received from Mr. Dunn, of Mevagissey, on June 24th. According to his account he saw it from the cliffs as a dark coloured patch in the water, and next day took a boat, found it, and brought it ashore. It was between 20 and 30 feet long and 18 inches wide. It was far advanced in development, and the young fish being black could be seen in it "like currants in a cake," struggling to get out. A large number of larvæ were hatched from this spawn in the Plymouth aquarium, and some were preserved, but as I was absent when the spawn arrived no very careful study was made of it.

Each egg inside its cavity is rather large, 1·75 mm. or $\frac{7}{100}$ inch. The space between the egg and the envelope is also rather large. It appears evident from the description and figures of Agassiz that the sheet of spawn is simply formed by the outer surface of the egg-membranes being jelly-like and sticky, so that they become attached to one another before leaving the roe of the mother. It will be easily understood that if the eggs of the herring were to stick together in a singler layer, the membranes remaining soft and pliable instead of being stiff, and the whole layer were to float in the sea, we should have just the state of things which we find in the spawn of the angler.

Dr. Fulton gives some observations on the roe of the fish as taken from the female. He states that one taken from a fish nearly 4 feet long, was 36 feet in length, 10 inches broad in the centre, and 6 inches at the ends. The number of the eggs was computed to be 1,345,000. The eggs were pear-shaped and attached to the inner surface of the roe by the narrow end. It would appear from these remarks, although they are not sufficiently clear, that the roe forms a very long tube which is coiled up inside the mother, and if we infer that the eggs are attached, before they are quite ripe, by their stalks, we can understand how they could become connected together by their sticky sides, and so form the ribbon-shaped sheet of a single layer of eggs which we know to be the condition in which they are shed into the water. The existence of the stalks holding the eggs in the roe until they have become attached together by their sides, explains why they stick together in a single layer, and not in a mass. It

FIG. 148.—Three of the eggs of the Angler, from a sheet of the spawn, alive and magnified; after Agassiz.

is at any rate clear that the sheet of jelly containing the eggs is simply formed of egg-membranes corresponding to those in which other fish eggs are enclosed.

Each egg has a single large oil globule which, when the fish develops, is situated at the hinder end of the yolk-sac: the yolk is undivided.

It is characteristic of the larva, even before it leaves the egg, that it develops a large amount of black pigment, although the yolk and the substance of the body are quite transparent. The

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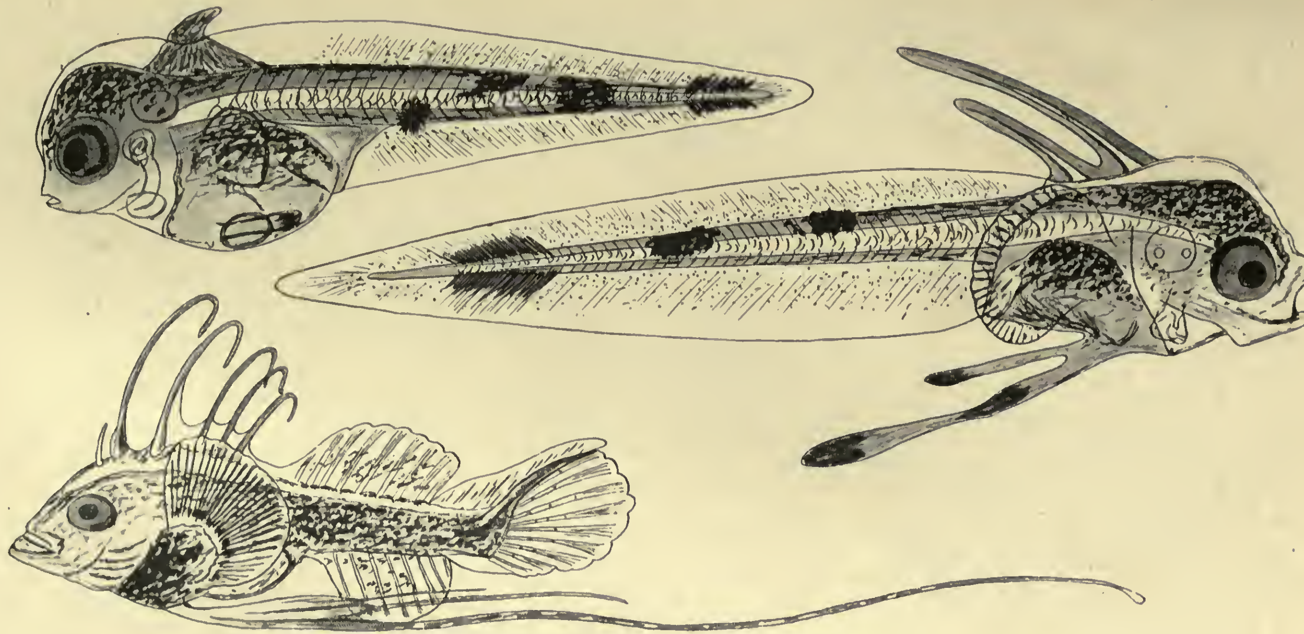

FIG. 149.—Larva of the Angler newly hatched; after Agassiz.
FIG. 150.—Larva of the Angler, later stage of development; after Agassiz.
FIG. 151.—Larva of the Angler at a very late stage, towards the end of its active swimming condition.

larva when hatched is much more advanced in development than those of most fishes with separate floating eggs. The mouth is open, and the yolk much reduced. But a still more striking peculiarity is that while there is as usual a transparent fin-membrane along the middle line of the body and tail, there is on the back just behind the head a short thick tentacle arising from a protuberance of the body (Fig. 149). Thus early is the importance of the tentacles formed by the dorsal fin-rays indicated. The two pairs of side fins are present as mere skin-folds. Very soon however, when the larva is a few days old, the pelvic or throat-fins begin to lengthen into long tentacles. As the fish grows in size, while the longitudinal fin membrane round the tail region remains unaltered, the tentacle on the back of the head grows larger, and also that of the throat-fin. Then a second tentacle grows out behind the first on the back, and another in the throat-fin (Fig. 150). The number on the back increases to four, and in the throat-fin to three: they become very long, especially the latter. Now the bony rays of the second dorsal fin and of the ventral and tail fin appear, while the filaments of the throat-fin grow so much that the first is more than twice as long as the body of the fish, and the second reaches to the end of the tail. The breast fin is a large fan-shaped paddle with a circular edge. The fish all this time swims freely near the surface or in the open water, not resting on the bottom, and in accordance with this fact the body is as yet narrow from side to side and deep from the back to the belly. The front dorsal tentacles are also long, and it turns out that those first developed are the five hinder ones, the first, which in the adult is shorter than the second, developing last in front of the others. A later free-swimming stage is figured by Dr. Günther in his *Introduction to the Study of Fishes*, in which the rays of the throat-fin are somewhat shorter, but still projecting beyond the membrane of the fin, the rays of the enormous breast-fins also project, and the rays or tentacles on the back of the head are furnished with little branched flaps of skin on their sides, except the first which has a forked flap at the end very like that of the adult fish. In this stage the fringed flaps round the edge of the lower jaw have also appeared, the body is broader and flatter, and it is evident that the young fish is gradually passing into the condition of the fully developed angler.

THE BLENNIES

THESE are fishes with soft slimy skins, in which the scales are very rudimentary or altogether absent. The dorsal fins occupy the greater part of the length of the back, and may be continuous from end to end, and also with the tail-fin, or may be partially divided into two or three distinct fins. The vent is usually a little in front of the middle of the body, and the ventral fin extends from thence to the base of the tail fin, or is continued into the tail fin. The breast fins are rounded and large, the throat fins either small and placed in front of the breast fins, or absent altogether.

Blennies belong especially to the shore, lurking about in crevices of rocks, or between and under stones, or among sea-weed, and are commonly found between tide-marks. They are spread generally along the temperate and tropical coasts. The sea-cats or cat-fishes are different from the majority of the family, being of large size, and living in rather deep water. The eggs of the blennies, if deposited at all, are, so far as is known without exception of the fixed attached kind, adhering together in masses, and undergoing development on the ground. But the viviparous blenny brings forth its young alive.

The British members of the family are :—

I. Species in which the dorsal fin is imperfectly divided into two, and separate from the tail fin ; no scales ; pelvic fins present.

1. **The Common Blenny** or **Shanny.**—Head smooth, without any appendages ; notch between the two divisions of the dorsal fin very slight.
2. **The Gattorugine.**—A fringed, fleshy tentacle above each eye.

3. **The Butterfly Blenny.**—Front part of the dorsal fin elevated, and having a deep black spot, surrounded by a white ring.
4. **Montague's Blenny.**—Having a fold of skin between the eyes, fringed with small tentacles.

II. Species without any division in the dorsal fin; caudal separate; throat-fins very small; small scales present; two pairs of tentacles on head.

5. **Yarrell's Blenny.**

III. Species in which the body is elongated with a single low dorsal fin, and the tail-fin not separate.

6. **The Gunnel** or **Butter-fish.**—Body long and slender; a row of black spots with a white ring round each along the base of the dorsal fin on each side.
7. **The Viviparous Blenny.**—Body tapering towards the tip of the tail, and a long notch in the edge of the dorsal fin at the tail end.

IV. Species of large size, with tail small and separate; no throat-fins; scales rudimentary.

8. **The Sea-cat, Wolf-fish,** or **Cat-fish.**

At St. Andrews Mr. Holt saw the spawning of the butter-fish or gunnel in the aquarium in February. The eggs were adhesive, and the parents were seen to roll the mass of eggs into a ball by coiling their bodies round them, not both parents together, but the male and female in turns. It has been observed by Professor McIntosh and Mr. Anderson Smith that in the natural condition the parents are found coiled round the balls of spawn, which are somewhat larger than walnuts, and not attached to anything. The spawn is shed from the middle of February to April.

The blennies proper all attach their eggs in a single layer over the sides of cavities between stones or in rocks, but it has not been observed with certainty whether it is the male or the female that guards and tends them. A large hollow bone, probably from the leg of an ox, on the sides of the cavity of which were attached the eggs of the butterfly blenny, was examined by me at Plymouth. A specimen of the fish was found in the cavity, and it was probably the male, but I did not note the sex. The yolk was of an orange-red colour, and quite impervious to light.

In the Firth of Forth specimens of the viviparous blenny in which the young were ready to be born, were found in February and March between tide-marks. The number of young is from 50 to more than 100. Each is about $1\frac{1}{2}$ inches long, and in all respects like its parent, all the development and transformations taking place within the roe: the two roes are united forming a single sac.

The Cat-fish or Sea-cat (*Anarrhichas lupus*).

Distinguishing Characters.—In the cat-fish the tail is small but distinct, and the rays of the dorsal fin diminish in length at the hinder end to the base of the tail-fin, while those of the ventral do not. The chief peculiarity is the character of the teeth: in the front of each jaw are a group of long curved canine teeth or fangs; in the lower jaw behind there is a double row of rounded grinding teeth on each side; in the roof of the mouth are three double rows, those in the centre flat, at the sides pointed. The colour is a bluish-grey, with a row of black bands passing straight from the back more than half-way down the sides. It reaches 6 feet in length.

It is a northern fish, extending from Iceland and Greenland to the North Sea on the European side, and to Cape Hatteras on the American. In the North Sea it is not usually found south of the Dogger Bank, and is more common at depths over 30 fathoms. By means of its powerful teeth it is able to crush the hardest shells, such as that of the whelk, and it feeds upon shell fish, sea-urchins, and crustacea.

The eggs of the cat-fish (Fig. 152) are very large compared with buoyant eggs, and are shed in the winter months. The single egg is about 6 mm. in breadth, or more, that is nearly $\frac{1}{4}$ inch. Like those of the small blennies, the eggs are adhesive, and are attached to one another in a large mass, which is deposited on the sea-bottom in deep water. Whether the male or either parent takes care of the eggs there is no evidence to show: we can only consider from analogy that he probably does. A mass of the eggs was received alive, and in good condition by Professor McIntosh, at St. Andrews, in January, 1886. These were in an advanced stage of development, and many of the larvæ hatched out during the four or five days after they were received.

The length of the hatched larva (Fig. 153) is 11 or 12 mm. or nearly ½ inch. The body is transparent and slender, and surrounded in the middle line behind by a narrow fin-membrane. The yolk-sac is very large in proportion, and is longer from its attachment downwards than in the direction of the length of the fish ; it is attached therefore by a rather narrow base. In the middle of its front surface is a large single oil globule. The yolk is straw-coloured and somewhat transparent, and on its surface is a network of blood-vessels. There is some pigment in the eyes and on the back of the head, but scarcely any elsewhere. The mouth is open, but small. Some of these larvæ,

FIG. 152.—Eggs of the Cat-fish, natural size ; after McIntosh.

hatched at the end of January, lived in the St. Andrews laboratory until May 14th, by which time the yolk was all absorbed, the jaws and teeth well developed, and delicate fin-rays had appeared in the longitudinal fins and tail-fin (Fig. 154). The eye was relatively much larger than in the adult. The shape was that of the full-grown fish, and the colour was a dark smoky-brown except on the belly. The fish had not grown greatly in length : the exact measurement is not given, but from the figure it appears to have been about ⅗ inch. It is interesting to note that the absorption of the yolk which in the case of a larva like that of the plaice, occupies about a week, lasted in the cat-fish three months and a half, and also that while in the plaice the larva has to feed itself for about two months before it has completed its development and reached the perfect condition, in the cat-fish the development of the skeleton and all the

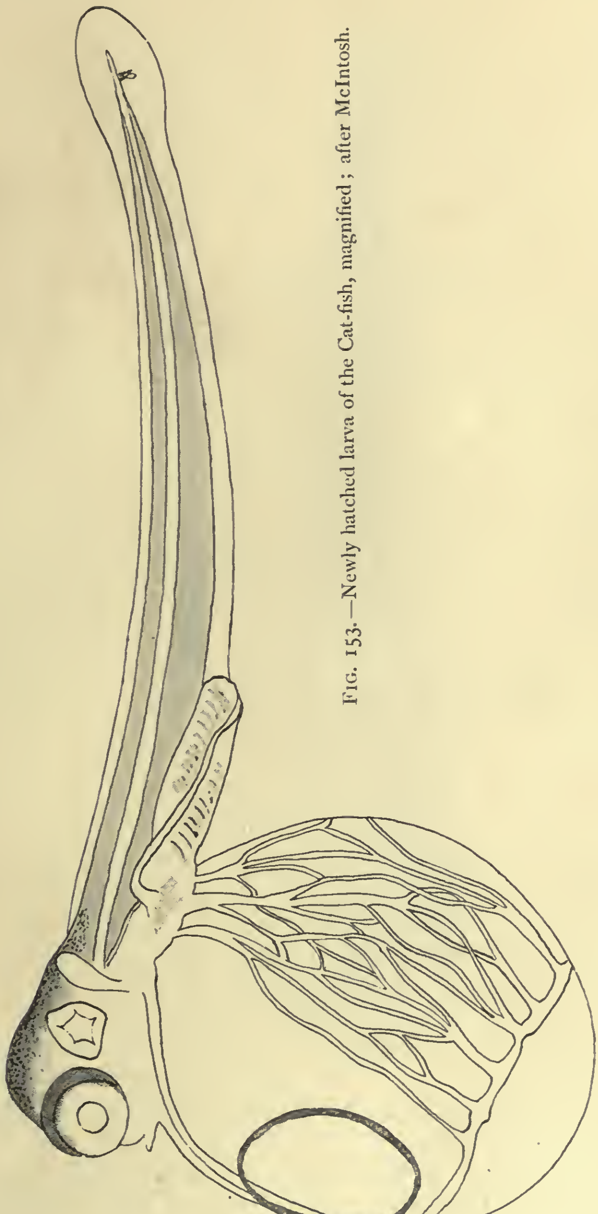

FIG. 153.—Newly hatched larva of the Cat-fish, magnified; after McIntosh.

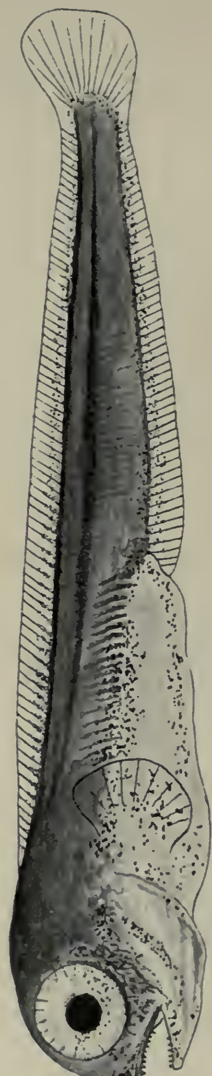

Fig. 154.—Young living Cat-fish ⅜ inch long, reared in the St. Andrews Laboratory, about 3½ months old, just after the absorption of the yolk; after Prince.

characters of the perfect fish are nearly complete by the time that the yolk is all exhausted.

At St. Andrews specimens of the cat-fish 6⅜ to 8¼ inches long were obtained in July and August, and must have been a year old.

THE SUCKER FAMILY

THIS family includes only fishes with a sucker on the belly, which are found in the arctic and temperate regions of the northern hemisphere. There are no ordinary scales ; the skin is either entirely unarmed or provided with scattered rough bony tubercles. There are two dorsal fins or only one. The throat-fins, in front of the breast-fins, form the sucker ; the fin-rays are short and spread out round a shallow pit, and outside them is a ring of skin ; the sucking action is produced simply by the contraction of the muscles in the centre. These fishes live on the shore, and up to a certain moderate depth. They have no air-bladder.

The eggs are comparatively large and adhesive, deposited in clumps or masses, and the male parent guards them.

The Lump-sucker (*Cyclopterus lumpus*).

Distinguishing Characters.—The massive shape, marked with longitudinal ridges and rough tubercles are characteristic of this fish. The first dorsal fin is entirely buried in a fleshy ridge in the back, the edge of which is armed with a row of tubercles. The second dorsal and the ventral are of the usual structure, and opposite to one another. The stalk of the tail is short. The breast-fin is large, and the sucker large and powerful. There are three rows of large tubercles on each side, besides numerous minute ones all over the skin.

The southern limit of the lump-sucker is the Bay of Biscay ; northward it extends to Iceland, Greenland, and the north coast of Russia. On the American coast it extends southward to

Cape Hatteras. It is much more common on the coasts of Scotland than on those of England or Ireland.

Breeding.—The two sexes differ in size and colour, the female being large and dull coloured, generally of a uniform blue, yellowish-white beneath. The male is smaller and, with some blue on the back, has its sides and belly of a brilliant red and yellow. In Scotland the male is called the "cock-paidle," the female the "hen-paidle." The exact reason why the fish is called a paddle I do not know.

Dr. Fulton found that in fish $17\frac{1}{8}$ to $18\frac{5}{8}$ inches long the number of ova was from 79,000 to 136,000. Spawning takes place in March, April, and May, and the whole of the eggs seem to be shed at one time in one mass. There are, however, holes in the mass to allow the water access to the interior. The spawn is

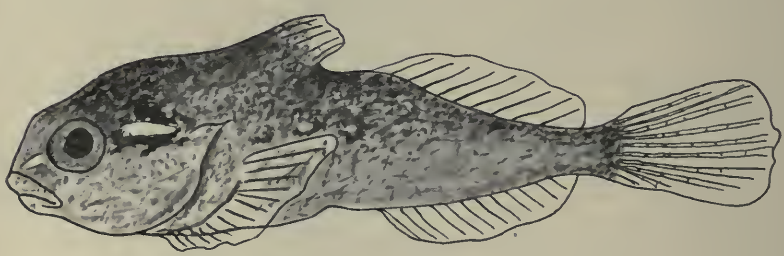

FIG. 155.—Young Lump-sucker $\frac{2}{5}$ inch long; after Agassiz.

attached to rocks or piles, and is as often as not more or less exposed at low water in spring tides. The male always remains guarding the eggs and keeping the water moving over them by the action of his breast fins. The colour of the eggs varies from red to pale-yellow or nearly white. Individually the eggs are large, measuring 2·6 mm. in breadth or over $\frac{1}{10}$ inch. The yolk is but slightly transparent, and contains numerous oil globules of various sizes. The egg membrane is thick and firm, and neighbouring eggs only stick together over small areas of the surface.

The little fish when first hatched is not quite $\frac{1}{5}$ inch long. The development is far advanced, the body coloured green and opaque, the mouth and jaws well developed, the sucker already formed, and the breast-fins have fin-rays. The central fin-membrane round the tail-end of the body is present, but it has primitive fin-rays. There are, however, no tubercles in the skin, the surface is smooth, and the shape more like that of a tadpole than of the parent fish.

The young at somewhat later stages are abundant among weeds on the shore, and are also frequently taken at considerable distances at sea, adhering to detached floating pieces of seaweed. Fig. 155 shows the appearance of a specimen $\frac{2}{5}$ inch long.

The Diminutive Suckers (*Liparis vulgaris* and *Liparis Montagui*).

It is not necessary for the purpose of the present work to distinguish between these two kinds. They are sometimes called sea-snails. They have a soft, movable skin without scales or tubercles. The sucker is very similar in structure to that of the lump-sucker, but there is only one undivided dorsal fin, the rays of which are of uniform, very moderate length. The ventral fin is similar ; both extend to the root of the small tail-fin. The head and body are smooth and rounded, the tail tapering and flattened from side to side. The colours are brown or yellowish-brown with lines or spots. The greatest length of these fish is not more than 6 inches.

Like the lump-sucker they range to the arctic regions. They haunt the shore, and are usually common in estuaries. In relation to fishes of commercial value their only importance is that their spawn has been frequently mistaken by naturalists as well as by fishermen for the spawn of the herring. The spawn forms little rounded masses of eggs attached to one another, and fastened to zoophytes or red sea-weed. It is usually found on one particular zoophyte called *Hydrallmannia*. The mass is about as big as a marble or larger. Individually the eggs are very similar in size to those of the herring, but a little smaller, namely, 1·27 mm. or $\frac{1}{20}$ inch in breadth. But the mass of eggs can be usually distinguished from a clump of herring spawn by its more compact rounded shape, the masses of herring eggs being more irregular. Herring spawn is also more transparent and delicate looking, the membranes enclosing the eggs being thinner. With the aid of the microscope there is no difficulty in distinguishing the spawn of the suckers, for in these eggs the yolk is transparent, and contains a number of oil globules.

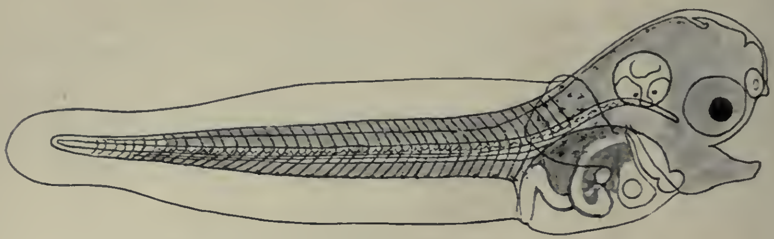

FIG. 156.—Newly hatched larva of the Diminutive Sucker or Sea-snail.

The hatched larva of the sucker (Fig. 156) is as different as possible from that of the herring, the head and body being plumper, and the vent placed near the head, instead of near the end of the tail as in the herring.

APPENDICES

APPENDIX I

VIVIPAROUS FISHES

THE fact that in certain species among cartilaginious fishes (*i.e.*, sharks and rays) the whole development of the egg takes place within the body of the mother, has been mentioned in the text. In these cases there is a quantity of yolk in the egg, as in cases in which the eggs are laid, and when the embryo is advanced in development the yolk is contained in a globular bag or umbilical vesicle, attached to the embryo by a stalk. In many species of sharks there is no attachment or connection between the oviduct in which the embryo is contained, and the embryo or yolk-sac. But in these cases the inner surface of the oviduct is furnished with finger-like processes, called villi, and these secrete a nutritious liquid which aids to some extent in the nourishment of the embryo. This is the case in the spur-dogfish and others. In several other sharks, including the large ferocious species of tropical seas, the yolk-sac, when the yolk is nearly consumed, becomes attached to a certain area of the inner surface of the egg-tube or oviduct, and the blood-vessels of the yolk-sac belonging to the embryo come into close proximity with the blood-vessels of the adjoining surface of the oviduct. Projections and depressions are formed on the two surfaces or membranes, maternal and embryonic, and the blood-vessels of the yolk-sac take up nourishment and oxygen from the blood-vessels of the oviduct. This condition forms what is called a *placenta*, very similar to that which is formed in the gestation of *mammals*, or animals which have hair and which give milk.

The smooth hound (*Mustelus vulgaris*) of British seas has no placenta, the yolk-sac remaining always free and separate from the walls of the oviduct but in a closely allied species (*Mustelus lævis*) occurring in the Mediterranean, a well-developed yolk-sac placenta is formed. In the latter case the egg is at first surrounded by a thin flexible egg-shell, between which and the egg proper there is a wide space filled with liquid or "white." The egg-shell remains even when the placenta is formed. There are often three or four embryos in each oviduct, each embryo having its own placenta.

No placenta has been discovered in any family of rays, but on the other hand the amount of nourishment supplied to the embryo in the viviparous forms by the secretion of the walls of the oviduct is very great. The gestation of several of the sting-rays and eagle-rays (*Trygonidæ* and *Myliobatidæ*) of the Indian Ocean has recently been particularly investigated by Professor Wood-Mason and Surgeon A. Alcock in specimens obtained by the Indian Marine Survey steamer *Investigator*. In *Trygon Bleekeri* the villi were found uniformly scattered over the surface of the walls of the uterus or dilated oviduct. One specimen examined was 3 feet across the pectoral fins, and contained an embryo 8 inches across. As there were no special organs for the absorption of the uterine milk, as the secretion may be called, it was concluded that it was taken through the mouth or spiracles and digested in the stomach. This conclusion was confirmed by the very curious arrangement discovered in another species of sting-ray called *Pteroplatæa micrura*. In this case the villi were confined to the part of the uterus near the spiracles of the fœtus, and a bundle of very long villi actually passed through each spiracle into the throat of the fœtus, as seen in Fig. 157. The spiracles were very large. These villi thus pour a nutritive secretion into the throat of the fœtus, much as the teat of a mammal pours out milk, but without any sucking action on the part of the fœtus. In these cases the young, when ready for birth, is much larger and heavier than the egg from which it arose.

Many species of bony fishes also bring forth their young alive, and in a fully developed condition, although this mode of propagation is not exhibited by any of the commercially valuable species inhabiting British seas. One small marine fish which is common on British shores is viviparous, namely the viviparous blenny (*Zoarces viviparus*), and there is only one other marine species occurring in Europe which has this peculiarity, namely the so-called Norway haddock, *Sebastes norvegicus*. These two belong to quite distinct families, the former to that of the blennies, the latter to the Scorpænidæ, and there is no close similarity between them in structure and habits. *Zoarces* is an elongated eel-like form without scales, with short and flexible fin-rays, and with rudimentary pelvic fins, while *Sebastes* is a much larger fish, of narrow compact shape and with strong spines and scales. *Zoarces* haunts the shore and lurks under stones, while *Sebastes* lives in deeper water and swims about boldly. Both, however, are northern species, the Norway haddock extending from Spitzbergen to the south-west coast of Norway, but having rarely been taken on the more northern coasts of Britain, while the viviparous blenny is common on the east coast of Britain, in the Baltic, and along the shores of Scandinavia, but is very seldom found on the south coast of England or the west coasts of Ireland and Scotland.

Other species of these families living in other parts of the world are also viviparous : on the Pacific coast of North America no less than fifty-one species of Scorpænidæ occur which produce living young. This coast is remarkable above all other parts of the world for the extraordinary number of viviparous species among the fishes which live upon it. In

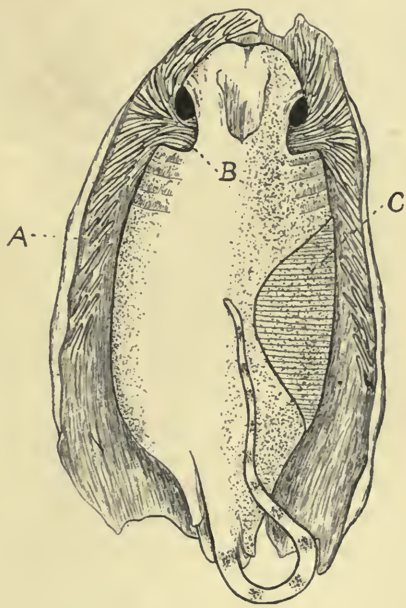

FIG. 157.—Fœtus of an Indian Sting-ray (*Pteroplatæa*) as seen when the uterus is cut open along its dorsal side, the uterine filaments or villi passing on each side into the wide spiracles of the fœtus. (After Wood-Mason and Alcock.) A, villi on inner surface of oviduct ; B, longer villi passing into the spiracle ; C, end of the left pectoral fin which is rolled round the body.

addition to the Scorpænidæ there are a number of species forming the family Embiotocidæ, which is confined to the North Pacific Ocean. These fishes live near the shore, and closely resemble the wrasses in habits, appearance, and structure, most of them being brilliantly coloured.

Another family of bony fishes in which viviparous reproduction takes place is that of the Cyprinodontidæ, which are mostly freshwater fishes closely similar to the carps. Cyprinodontidæ signifies toothed carps, these fishes having teeth in the jaws, while the jaws of the carps are toothless. They are fishes of quite small size, and occur in south Europe, and in the warmer parts of the American continents.

The fact that viviparous reproduction, or the internal development of the eggs, is found to occur in several widely distinct families, shows that its origin is due to circumstances which may affect any family of fishes without reference to its relationship with other families in structure and descent. What these circumstances are it is difficult to say. We have good reason to believe that viviparous reproduction, in whatever division of the animal kingdom it is evolved, is always a secondary modification; that at first eggs were always expelled from the body of the mother to undergo their development, and that in certain cases the expulsion is delayed so that development goes on in the ovary or in the egg-tube. Internal fertilisation must necessarily precede internal development of the ova, for the eggs cannot begin to develop until they are fertilised. We know that the arrangement of the roes in the bony fishes was in existence before internal fertilisation or internal development occurred. We know that in certain species, as has been mentioned in the text, the males have developed a very definite interest in the female and the eggs. There is evident in these cases an association between the perception of the female and her eggs, and the expulsion of the milt. It is not difficult to understand how this association might be so developed that the milt in certain species came to be introduced into the ovary, and so the eggs were fertilised internally.

In animals in which internal fertilisation takes place the milt is usually injected by some kind of intromittent organ acting as a penis, and in viviparous bony fishes we find some such organ present in the males. In the viviparous blenny it is merely an elongated papilla on which the testicular canals open. In some Cyprinodonts there is in the male a tube passing down the front edge of the ventral fin, and the milt passes through this tube. The ventral fin is elongated, and with the tube forms an intromittent organ. In the females of these species the opening of the oviducts is covered by a special scale, which is free on one side but not on the other. The male organ in some individuals is turned to the right, in others to the left, and in some females the opening beneath the special scale is to the right, in others to the left. Copulation thus takes place sideways, a left-sided male pairing with a right-sided female, and *vice versâ*.

In the viviparous blenny copulation and fertilisation take place in September. The eggs during their formation, or growth to the ripe condition, are contained, as in all bony fishes, in chambers in the ovarian substance, which chambers are called follicles. Whether fertilisation occurs before the eggs have left the follicles is not stated, but they certainly leave the follicles and lie free in the cavity of the ovary at a very early stage of development. Like the eggs of species which are not viviparous, the eggs of *Zoarces* are contained in a spherical egg-membrane, which when the development of the embryo has reached a certain stage bursts, and sets the developing fish free in the ovarian cavity. The eggs are thus hatched in the interior of the ovary, whereas in other cases they are hatched in the sea after they have been expelled from the parent fish. It has been estimated that this hatching takes place about twenty days after fertilisation. After hatching the larvæ remain in the cavity of the ovary for a considerable time, and go through the whole of their further development and transformation in this situation. The young, in fact, are not born until about four months after fertilisation. In the Firth of Forth females in which the young were on the point of escaping were observed in February and March. The newly born young are about 1½ inch long, and in all respects similar to the parent in structure. It is thus clear that either a larger quantity of yolk in the egg or some other supply of food must be available for the larvæ in the ovary of *Zoarces* to enable them to develop to this size and condition, considering the imperfect condition of free fish-larvæ at the moment when the yolk is all consumed. The explanation is that the quantity of yolk is not large, but that the larvæ are nourished also by an albuminous liquid formed in the interior of the ovary as a secretion from its walls. The number of young produced at a birth varies very much in different females, and depends chiefly on the size of the latter. Females of 7 or 8 inches in length are found to contain from 20 to 40 young, those of 8 to 10 inches from 50 to 150, while larger specimens have been found to contain 300 young or even more. Some specimens have been found in the gravid condition in summer and autumn, so that there is reason to conclude that fertilisation takes place in some cases in spring and birth in autumn, though it is by no means proved that the same female breeds twice in a year.

In Fig. 158 is shown the appearance of the developing egg of the viviparous blenny before hatching, taken from the ovary on September 28th; it is magnified 12 times. Fig. 159 represents one of the young nearly ready for birth, taken from the ovary on November 24th. The little projection on the ventral surface beneath the pectoral fins is the remains of the yolk-sac. The figure represents the young fish magnified to twice its length. The little circle below represents the actual size of the egg, and the line the actual length of the young fish at the stage mentioned. The process of development and gestation in other viviparous fishes is by no means exactly or closely similar to that which is observed in the viviparous blenny. Great differences are found to exist in the degree to which the nourishment of the embryo is derived from the yolk of the egg or from nutritious secretions of the ovary. The two sources of nourishment often exist together, but generally the more abundant one is, the more diminished is the other, either being capable of supplying the place of the other. We may consider those cases in which the nourishment is derived chiefly from the yolk as being more primitive. Cases of this kind occur among the Cyprinodonts, for instance in the species of *Gambusia*.

Gambusia patruelis is a species living in the fresh waters of Virginia. The adult males are only $1\frac{1}{2}$ inch long, the females $1\frac{3}{4}$ inch. The ventral (so-called anal) fin has the anterior rays elongated to form an intromittent organ, but there is no tube running down these rays. In copulation the male has been observed to have his head turned towards the tail of the female, and to insert the end of the prolonged ventral fin into the opening of the ovary. The ovaries of the two sides are united

FIG. 158.

FIG. 159.

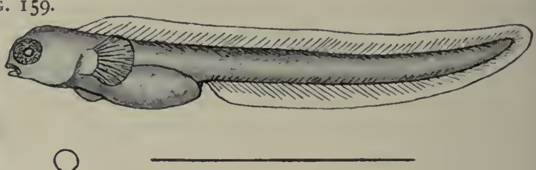

FIG. 158.—Developing Egg of the Viviparous Blenny taken from the ovary Sept. 28th. Magnified 12 times. Fig. 159, Young of the Viviparous Blenny, taken from the ovary of the mother on Nov. 24th; magnified twice. The circle and straight line show the actual size of the egg and length of the unborn young fish. (After Rathke.)

into one, and at each gestation twenty to twenty-five yellowish eggs each about $\frac{1}{12}$ inch in diameter are produced. These eggs do not leave the follicles in which they are formed, but an opening is formed at the outer part of the follicle; through this opening sperms enter and fertilise the egg, which goes on developing in the follicle. It is very remarkable that in this case the ovary has lost its tubular or sac-like character, and the germinal tissue is exposed in the general body-cavity, the young escaping at birth by an abdominal pore. Another peculiarity is that the egg does not appear to be provided with an egg-membrane, a structure which is unnecessary in an egg that develops within the follicle in which it is produced. The walls of the follicle are richly supplied with blood-vessels, and by this means the developing fish is provided with oxygen; but although the follicle contains liquid around the embryo this does not appear to contribute to the nourishment of the latter, for the yolk is not exhausted until the young fish is completely developed and ready for birth. When the young fish is born its fins and fin-rays are completely developed, and it resembles its parent in everything except size.

In the curious *Anableps*, a Cyprinodont of Guiana and Brazil, which is distinguished by the interesting peculiarity that the upper half of its eye is formed to see in the air, and the lower half to see in the water, the yolk is soon exhausted, and the nourishment of the embryo during the greater part of gestation is provided by the nutritious albuminous liquid secreted by the walls of the follicle. This liquid is absorbed by papillæ on the walls of the yolk-sac, which remains and enlarges after the yolk has all been absorbed. The papillæ are situated along the course of the veins of this abdominal sac, and the nourishment they absorb is thus taken up by the blood, and so supplies material for the growth and development of the embryo.

In the Embiotocidæ of the Pacific coast, which appear to be known in California as "surf-perches," the two ovaries in the female are united, forming a single closed sac, the germinal folds in which the eggs are produced depending lengthwise from the dorsal wall of the cavity and so partially dividing it into several compartments. The embryos undergo their development outside the follicles in which the eggs are produced, lying between the folds of germinal tissue, which are abundantly supplied with blood-vessels. There is very little yolk, and consequently the embryos are nourished by a secretion of the walls of the ovary. At an early stage, it is stated, the remains of the milt introduced into the ovary in copulation are swallowed by the embryos. In later stages the hinder part of the intestine is much enlarged and its inner surface is provided with long processes (villi). The ovarian secretion appears to be swallowed by the embryo and absorbed by these villi of the dilated hind-gut. Another peculiarity in these embryos is that the median fins (dorsal, ventral, and tail-fin) are much developed, and their membranes between the fin-rays are produced into thin delicate processes. Both the fins and these processes are richly supplied with small blood-vessels, and act the part of gills during the period of gestation, their function being to absorb oxygen from the blood in the ovarian folds with which they are in contact. This arrangement approaches somewhat to that which exists in the placenta of mammals, but the relation of the embryonic structures to the maternal is much less intimate than in the latter, and the function of the vascular membrane appears to be only respiratory, not nutritive.

In the Embiotocidæ the eggs are fertilised in the follicles in which they are produced, but escape from these soon afterwards to develop in the ovarian cavity. The ovary frequently contains forty or fifty young fish, which at birth measure 2 inches or more in length.

The gestation of the Scorpænidæ does not appear to have been completely investigated, but it has been found that in gravid specimens of the Norway haddock the embryos are small and very numerous; the number in a single fish was estimated at fully a thousand. At a certain stage which has been described, the individual embryos were slender and small, not quite $\frac{1}{4}$ inch in length. The yolk-sac was large in proportion, and some embryos were enclosed in an egg-membrane, while others had hatched. The embryos were situated in the spaces between folds and processes of the germinal tissue of the ovary; these processes were highly vascular, and doubtless served for the respiration of the embryos, that is to say, the latter derived from the blood in them the oxygen necessary for their existence.

APPENDIX II

THE FISHING GROUNDS

(*See Maps: "Fishing Grounds of the British Islands" and "West Coast of Europe."*)

THE area exploited by the fishermen of the British Islands extends to Iceland on the north, and to the coast of Spain and Portugal on the south, while to the westward it is limited by the deep basin of the Atlantic. Drift-net fishing in the open sea is unaffected by the depth of the water or the nature of the bottom, and the distance from the coast to which it is extended depends, therefore, on the presence of the fish in sufficient abundance, and the demand or markets that can be supplied. In line and trawl fishing, on the other hand, the depth and character of the bottom are of great importance.

The 100-fathom line passes outside the British Islands, bounding a plateau on which all these islands, including the Hebrides, the Shetlands, and the Orkneys, are situated. But the Faröe Islands and Rockall lie beyond it. This line runs parallel to the coast of Portugal and Spain at a very short distance off, along the west coast of France it begins to diverge farther from the land; it passes outside the entrances of the English Channel and St. George's Channel at a considerable distance, and then runs along the west of Ireland and the Hebrides. Passing to the east, round the north of the Shetland Isles, it approaches the coast of Norway, and then bends round to the south-east, bounding a deep channel which runs close to the southern coast of Norway into the Skager Rack. Around the coast of Iceland and the Faröe Islands the 100-fathom line is nowhere at a great distance, so that the extent of shallow water is confined within narrow limits on the shores of these islands. Beyond the 100-fathom line the slope of the bottom is everywhere rather rapid, descending on the west to the basin of the Atlantic, on the north to that of the Arctic Ocean.

The 50-fathom line on the whole follows more closely the contour of the actual coast line. It sends a pointed tongue into the entrance of the English Channel, runs round the outside of the Scilly Islands, and then forms a narrow channel between England and Ireland, but nearer to the coast of the latter. It runs at no great distance from the south and west coasts of Ireland, bounds a channel between the Outer Hebrides and Scotland, as well as numerous depressions in the firths and channels on the west coast of Scotland, runs northwards so as to pass round the outside of the Shetlands, and then passes down the east coast of Scotland in an irregular line. At about the latitude of the Farn Islands the 50-fathom line turns to the east, and at the second degree of east longitude runs north again to reach the edge of the Norwegian depression previously mentioned. Thus to the east of Scotland and the Orkney and Shetland Islands there is a depression of depths between 50 and 100 fathoms, while to the south and east of this depression the depth is nowhere over 50 fathoms except in one or two isolated pits : this shallow area includes the whole of the English Channel.

To the east of the depression, opposite the west coast of Jutland, lies the Great Fisher Bank, bounded by the 40-fathom line to the north and west, but outside the 30-fathom line. Lying obliquely across the broadest part of the North Sea south of the Great Fisher Bank is the Dogger Bank, bounded by the 20-fathom line all round, and rising at its south-west corner to within 10, 9, and even 7 fathoms of the surface. South of the Dogger Bank is a narrow depression descending to 50 fathoms at its deepest part, but limited in extent. This is the Great or Outer Silver Pit. Along the shores of Holland and Germany the 20-fathom line is thirty, forty, and even fifty miles from the lines of islands, Frisian and North Frisian Islands, which fringe these shores. These shallow grounds are what the trawlers of Hull and Grimsby call the Eastern Grounds. Between the 20-fathom line and the Dogger Bank the depth is greater, but does not exceed 30 fathoms.

The 20-fathom line to the north of Holland passes right across the North Sea to the English coast, bounding the Silver Pit on the south. South of this line the greater part of the North Sea as far as the Straits of Dover is less than 20 fathoms in depth. There are, however, isolated depressions here and there. Narrow small pits occur off the mouth of the Humber, called by the fishermen Little Silver Pit, Sole Pit, and Coal Pit. Off the coast of Norfolk are a number of banks and shoals in the form of narrow ridges, mostly lying between north-west and south-east. Further south off the east coast of Norfolk and Suffolk, and running parallel to that coast there is a depression descending in some places to 30 fathoms. To the east of this depression there are a number of narrow ridges running north and south, and rising to 11 or 12 fathoms from the surface. One of these is marked on the chart as the Brown Ridge, and they may be called the Brown Ridges.

The drift-net fisheries are prosecuted on the largest scale by Scotch boats, Yarmouth and Lowestoft boats, and boats belonging to Mount's Bay and Plymouth. There are drift-net boats at a very large number of ports all round the coast, but those of the districts mentioned carry on the fishing in the regions where it is most productive, not merely in the neighbourhood of their own ports. The principal herring fishery is that carried on in spring, summer, and autumn, on the north and east of Scotland, and off the east coast of England. A considerable number of English, Scotch, and Manx boats also take part in the herring fishery off the east coast of Ireland. Mackerel fishing is principally carried on off the south coast of Ireland, Mounts Bay, and the coast of Devon and Cornwall in the earlier months of the year, and a large number of boats from Lowestoft resort thither to take part in it. In September and October as well as in May and June Lowestoft boats fish mackerel off their own coast. The pilchard fishery is carried on entirely by Devon and Cornish boats off the south-west coast of England.

Trawling is extensively carried on within the 50-fathom line off the south coast of Cornwall and in the Bristol Channel. Large numbers of sailing trawlers belonging to Plymouth and Brixham use these grounds. The Mounts Bay grounds are visited chiefly in spring and summer, and the same is true of the grounds off the north coast of Cornwall. These grounds yield soles, turbot, brill, lemon dabs, plaice, hake, skates, and rays, John dories, tubs, sea bream, and other southern species, but haddocks are only occasionally taken and cod are not plentiful.

The eastern part of the Channel is less important as a trawling ground. The southern part of the North Sea is worked chiefly by sailing vessels belonging to Lowestoft and Ramsgate. These grounds resemble in their produce the grounds of the Channel, and differ considerably from the more northern and deeper parts of the North Sea. Cod and haddock are scarce; plaice are fairly plentiful, but small, the majority from 11 to 13 inches long, and the majority at the latter length mature; soles are fairly plentiful, turbot and brill not uncommon; lemon dabs are scarce; common dabs and whiting are abundant, grey gurnard are plentiful, and also tubs or latchets; weevers, the larger and the smaller species are very abundant on the Brown Ridges; rays and skate are fairly plentiful.

In the northern part of the North Sea, excluding the Eastern Grounds, the staple produce of the trawl always consists of haddock and plaice. Without these two kinds of fish, especially the former, the enormous fleets of steam-trawlers which now range these waters could not be kept at work at all. One hundred and fifty to two hundred boxes of haddocks are often landed at Grimsby by a steam-trawler after a week's fishing or even less on the Dogger Bank. Plaice are also fairly abundant on the Dogger, and some cod are taken, especially in spring. A few turbot are taken but soles are scarce. Lemon dabs are seldom taken on the Dogger, but are found in depths beyond 20 fathoms throughout the northern part of the North Sea.

The Eastern Grounds are worked by English vessels, mostly from Grimsby and Hull, in summer, from March and April onwards. They are less productive in winter. They are remarkable for the great abundance of small plaice taken on them, more than 250 boxes being often landed from a single voyage by a steam-trawler. Soles, turbot, and brill are also plentiful on these grounds, the soles being mostly large, but a large proportion of the turbot and brill small. Cod are scarce, lemon dabs absent, and haddock occur in very moderat numbers. Latchets or tubs are rather plentiful and of large size, and in this respect, as well as in several of the above features, the Eastern Grounds resemble the Brown Ridges. The bottom is composed of smooth sand, or muddy sand, with some gravelly and stony areas in parts.

The term Eastern Grounds is restricted in the Humber ports to the ground along the German and Danish coasts, but the shallow grounds along the north coast of Holland have a similar character, and are worked a great deal in summer by vessels from Grimsby and Hull, and by the Yarmouth fleet. These grounds being for the most part smooth and sandy, comparatively little "scruff" or unmarketable material is found upon them. Whelks and whelk-spawn are abundant, and also what the fishermen call teats—*i.e.*, *Alcyonium digitatum*. Edible crabs are taken in some numbers, and star-fishes of various kinds are numerous.

The grounds lying off the mouth of the Humber and Wash to a distance of about 60 miles are the home grounds of the Humber ports, and the Yarmouth and Lowestoft vessels fish to a considerable extent about the banks and shoals off the Norfolk coast. Plaice of various sizes are taken on these grounds, and also haddock, though not so plentifully as on more northern grounds. Soles, brill, and turbot occur, and also lemon dabs in moderate numbers. Cod and codling and gurnard are taken, but latchets are only occasionally seen. These grounds produce an extraordinary quantity of "scruff," of which the most abundant constituent is a form known to the fishermen as "curly cabbage," a fixed compound gelatinous organism (*Alcyonidium gelatinosum*). Hydroids (chiefly *Sertularia* and *Hydrallmannia*) are also abundant.

The grounds to the east and south-east of the Dogger are also fished, and produce chiefly haddock and plaice.

On the Great Fisher Bank few turbot or brill are taken, and soles are scarce. The fish belonging to the north and to deeper water are here most abundant, namely witches (*Pleuronectes cynoglossus*), haddock, cod, ling, halibut, and cat-fish. Large plaice are also taken in moderate numbers, but lemon dabs are scarce or absent. Megrims appear to occur in small numbers.

Along the English coast north of the Humber cod are extremely abundant in the spawning season, February and March, one steam-trawler often landing seventy or eighty score from a week's fishing. Plaice, lemon dabs, cat-fishes, ling, coal-fish, and haddock are also taken. Soles, turbot, and brill occur in the shallower water, long rough dabs and witches in the deeper. The grounds along the east coast of Scotland have a similar character.

In the last few years, since 1891, some steam-trawlers from Grimsby and Hull have trawled in the summer months off the south coast of Iceland, at depths from 6 or 7 fathoms up to 40 fathoms. Plaice and haddock are obtained in abundance, and of very large size, much larger than those caught in the North Sea; the majority of the plaice are from 27 to 33 inches in length, the haddock from 19 to 33 inches. Common dabs, whiting, witches, megrims, halibut, cod, ling, cat-fish, and skate are all plentiful. The so-called "Norway haddock," mentioned in Appendix I. as viviparous, is also taken in numbers, and landed for sale at Grimsby, where however it does not fetch a very high price.

In consequence of the great demand for fish, and the profit to be made by supplying this demand, the number of steam-trawlers belonging to Hull and Grimsby has become very large. It has been difficult for all these vessels to obtain constantly sufficient supplies of fish in the North Sea, and consequently they have gone long distances in various directions in search of unexhausted grounds. While some were discovering new trawling grounds on the coast of Iceland, others were shooting their trawls on the shores of the Bay of Biscay, landing their catches at Plymouth. In 1892 a number fished in Vigo Bay, on the north-west coast of the Spanish Peninsula. On these southern coasts hake often form the most important constituent of the catch.

Other Humber steam trawlers have fished for some months in the year in the Irish Sea and off the west coast of Scotland, landing their catches principally at Fleetwood. The extent of trawling ground along the west coast of Ireland is not very great, and I have not heard of any English trawlers making trial of it; but local boats of small size trawl in Galway Bay.

Long-line fishing is carried on over most of the trawling grounds mentioned in the neighbourhood of the British and Irish coasts. On the east coast the two principal ports for long-lining are Harwich and

Grimsby. At both of these ports welled smacks are used, and the cod caught are brought back alive in the well, and kept alive for a time in cod chests in the harbours. Whelks are largely used for bait, and the fishing grounds are about the Dogger Bank and off the north-east coast of England. Haddocks are also caught, as well as ling, skate, cat-fishes, and coal-fish. Cromer Knoll, a bank at the south end of the Outer Dowsing, is a favourite ground for long-lining in winter. Winter is the principal time for long-lining in the North Sea; after the beginning of April the smacks used to go to Iceland and Faröe and fish with hand lines, salting the fish on board. In summer and autumn the boats use hand lines in the North Sea. At present the Faröe, Shetland, and Iceland grounds are worked chiefly by large steamers fitted with wells, belonging to Grimsby, and these vessels bring back enormous numbers of halibut, as well as ling, cod, coal-fishes, cat-fishes, and skate. It is a striking sight to see the long rows of immense halibut and other fish laid out on the Grimsby pontoon when one of these vessels lands her catch from the deep northern grounds. In the North Sea in winter the bait chiefly used is whelks, but for the more northern grounds the vessels purchase small coal-fish and herrings at Lerwick to bait the lines.

North of the Farn Islands long-lining is carried on from a large number of small fishing ports on the English and Scotch coasts by means of smaller sailing boats without wells. Haddock are the fish principally caught by these boats, and mussels are chiefly used for bait.

In the south-west long-lining is carried on principally at Plymouth. The boats used are small and open, mostly about twelve tons burthen. The fish caught in largest numbers is conger, and this being a nocturnal fish the lines are always shot at night. Cod, ling, and pollack are also taken, as well as ray and skate. The grounds fished extend from Start Point to Land's End, and to a distance of 30 or 40 miles from the coast.

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