PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXVII.

SESSION 1912-1913.

LIVERPOOL:
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—
1913.

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PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents:

1886—87 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—88 J. J. DRYSDALE, M.D.
1888—89 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—90 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—91 T. J. MOORE, C.M.Z.S.
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1897—98 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—99 Prof. C. S. SHERRINGTON, M.D., F.R.S.
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1900—1901 Prof. PATERSON, M.D., M.R.C.S.
1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 Rev. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.
1906—1907 Prof. W. A. HERDMAN, D.Sc., F.R.S.
1907—1908 W. T. HAYDON, F.L.S.
1908—1909 Prof. B. MOORE, M.A., D.Sc.
1909—1910 R. NEWSTEAD, M.Sc., F.E S.
1910—1911 Prof. R. NEWSTEAD, M.Sc., F.R.S.
1911—1912 J. H. O'CONNELL, L.R.C.P.

SESSION XXVII., 1912-1913.

President:

JAMES JOHNSTONE, B.Sc.

Vice-Presidents:

Prof. W. A. HERDMAN, D.Sc., F.R.S.
J. H. O'CONNELL, L.R.C.P.

Hon. Treasurer:

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Prof. R. NEWSTEAD, F.R.S.
WM. RIDDELL, M.A.
Prof. SHERRINGTON, F.R.S.
E. THOMPSON.

Representative of Students' Section:

R. ROBBINS, B.Sc. (Miss).

REPORT of the COUNCIL.

During the Session 1912-13 there have been seven ordinary meetings and one field meeting of the Society.

The communications made to the Society at the ordinary meetings have been representative of almost all branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

By invitation of the Council, Prof. F. J. Cole, D.Sc., of University College, Reading, lectured before the Society, at the February Meeting, on "The Early Days of Comparative Anatomy," and the paper has been published in the Transactions.

The Library continues to make satisfactory progress, and additional important exchanges have been arranged.

The Treasurer's statement and balance-sheet are appended.

The members at present on the roll are as follows:—

Ordinary members - - - - - -	50
Associate members - - - - - -	6
Student members, including Students' Section, about	35
Total - -	91

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the twenty-seventh session was held at the University, on Friday, October 11th, 1912.

The President-elect (James Johnstone, B.Sc.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1911-1912 (see "Proceedings," Vol. XXVI., p. viii.) was submitted and adopted.
2. The Treasurer's Balance Sheet for the Session 1911-1912 (see "Proceedings," Vol. XXVI., p. xvii) was submitted and approved.
3. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, Prof. Herdman, D.Sc., F.R.S., and J. H. O'Connell, L.R.C.P.; Hon. Treasurer, W. J. Halls; Hon. Librarian, May Allen, B.A.; Hon. Secretary, Joseph A. Clubb, D.Sc.; Council, H. C. Beasley, G. Ellison, H. B. Fantham, D.Sc., B.A., Oulton Harrison, W. T. Haydon, F.L.S., W. S. Laverock, M.A., B.Sc., Douglas Laurie, M.A., Prof. B. Moore, M.A., D.Sc., Prof. Newstead, M.Sc., F.R.S., W. Riddell, M.A., Prof. Sherrington, F.R.S., and E. Thompson.
4. James Johnstone, B.Sc., delivered the Presidential Address on "Bergson's Philosophy of the Organism" (see "Transactions," p. 3). A vote of thanks was proposed by Prof. Sherrington, seconded by Mr. Haydon, and carried with acclamation.

The second meeting of the twenty-seventh session was held at the University, on Friday, November 8th, 1912. The President in the chair.

1. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 35).

The third meeting of the twenty-seventh session was held at the University, on Friday, December 13th, 1912. The President in the chair.

1. Dr. Fantham submitted a paper on "Some Protozoan Parasites found in the Gall Bladder of Fishes."

The fourth meeting of the twenty-seventh session was held at the University, on Friday, January, 10th, 1913.

1. On the motion of Prof. Herdman, seconded by Dr. Clubb, the congratulations of the Society were accorded to Mr. W. Gunn on his appointment to the Curatorship of the Newport (Mon.) Museum.
2. Prof. Herdman exhibited and demonstrated an apparatus for projecting microscopic preparations on to a screen.
3. Mr. H. C. Beasley exhibited, with remarks, some fossil casts of what was suggested to be a species of *Equisitites* from the Trias.
4. Prof. Herdman submitted the Annual Report of the Investigations carried on during 1912 in connection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 177).

The fifth meeting of the twenty-seventh session was held at the University, on Friday, February 14th, 1913. The President in the chair.

1. Prof. Cole, D.Sc., of University College, Reading, lectured before the Society on "The Early Days of Comparative Anatomy" (see "Transactions," p. 143).

The sixth meeting of the twenty-seventh session was held at the University, on Friday, March 14th, 1913. The President in the chair.

1. Dr. C. J. Macalister submitted an interesting paper on the effect of allantoin in promoting cell activity in organisms and in which the effects of injections in Hyacinths were described in detail.

The seventh meeting of the twenty-seventh session was held at the University, on Friday, May 16th, 1913. The President in the chair.

1. Mr. A. Scott, A.L.S., exhibited a series of plates of parasitic Copepoda, to be shortly published by the Ray Society.
2. Mr. Erik Hamilton exhibited a small tooth of some elephant, possibly a Mammoth, from the peat bed at Leasowe.
3. Mr. William Riddell, M.A., exhibited three rare species of Schizopods, new to the L.M.B.C. district, which, although bottom-living forms had been taken in surface tow-nets.
4. Mr. H. G. Jackson, M.Sc., submitted his L.M.B.C. Memoir on the Hermit Crab (see "Transactions," p. 495).

The eighth meeting of the twenty-seventh session was the Annual Field Meeting held at Hilbre Island, on Saturday, June 7th. At the short business meeting held at the Green Lodge Hotel, Hoylake, after tea, on the motion of the President from the chair, Dr. C. J. Macalister, was unanimously elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1912-1913.

A. Ordinary Members.

(Life Members are marked with an asterisk).

ELECTED.

1908 Abram, Prof. J. Hill, 74, Rodney Street, Liverpool.

1909 *Allen, May, B.A., Hon. Librarian, University, Liverpool.

1910 Barratt, Dr. J. O. Wakelin, Cancer Research Laboratory, University, Liverpool.

1888 Beasley, Henry C., Prince Alfred Road, Wavertree.

1908 Bigland, H. D., B.A., Shrewsbury Road, Birkenhead.

1903 Booth, jun., Chas., 30, James Street, Liverpool.

1912 Burfield, S. T., B.A., Zoology Department, University, Liverpool.

1886 Caton, R., M.D., F.R.C.P., 78, Rodney Street.

1886 Clubb, J. A., D.Sc., Hon. Secretary, Free Public Museums, Liverpool.

1910 Ellison, George, 4, Loudon Grove, Liverpool.

1910 Fantham, H. B., D.Sc., B.A., School of Tropical Medicine, University, Liverpool.

1902 Glynn, Dr. Ernest, 67, Rodney Street.

1913 Gowland, Dr., Anatomy Department, University, Liverpool.

1886 Halls, W. J., Hon. Treasurer, 35, Lord Street.

1910 Hamilton, Mrs. J., 96, Huskisson Street, Liverpool.

1896 Haydon, W. T., F.L.S., 55, Grey Road, Walton.

1912 Henderson, Dr. Savile, 47, Rodney Street, Liverpool.

1886 Herdman, Prof. W. A., D.Sc., F.R.S., Vice-President, University, Liverpool.

1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.

1912 Hobhouse, J. R., 54, Ullet Road, Liverpool.

1902 Holt, A., Crofton, Aigburth.

1903 Holt, George, 5, Fulwood Park, Liverpool.

1903 Holt, Richard D., M.P., 1, India Buildings, Liverpool.

1913 Howlett (Miss), Ethel, Holt Secondary School, Liverpool.

1912 Jackson, H. G., M.Sc., Zoology Department, University, Liverpool.

1898 Johnstone, James, B.Sc., President, University, Liverpool.

1894 Lea, Rev. T. S., D.D., The Vicarage, St. Austell, Cornwall.

1896 Laverock, W. S., M.A., B.Sc., Free Public Museums, Liverpool.

1906 Laurie, R. Douglas, M.A., University, Liverpool.

1912 Lyon, (Miss) Una, High School for Girls, Aigburth Vale, Liverpool.

1905 Moore, Prof. B., University, Liverpool.

1904 Newstead, Prof. R., M.Sc., F.R.S., University, Liverpool.

1904 O'Connell, Dr. J. H., Vice-President, 38, Heathfield Road, Liverpool.

1904 Pallis, Miss M., Tätoi, Aigburth Drive, Liverpool.

1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.
1903 Rathbone, H. R., Oakwood, Aigburth.
1890 *Rathbone, Miss May, Backwood, Neston.
1910 Riddell, Wm., M.A., Zoology Department, University, Liverpool.
1897 Robinson, H. C., Malay States.
1908 Rock, W. H., 25, Lord Street, Liverpool.
1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.
1908 Share-Jones, John, F.R.C.V.S., University, Liverpool.
1895 Sherrington, Prof., M.D., F.R.S., University, Liverpool.
1886 Smith, Andrew T., 21, Croxteth Road, Liverpool
1903 Stapledon, W. C., "Annery," Caldy, West Kirby.
1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.
1905 Thompson, Edwin, 1, Croxteth Grove, Liverpool.
1889 Thornely, Miss L. R. Nunclose, Grassendale.
1888 Toll, J. M., 49, Newsham Drive, Liverpool.
1891 Wiglesworth, J., M.D., F.R.C.P., Springfield House, Winscombe, Somerset.

B Associate Members.

1905 Carstairs, Miss, 39, Lilley Road, Fairfield.
1905 Harrison, Oulton, Denehurst, Victoria Park, Wavertree.
1910 Kelley, Miss A. M., 10, Percy Street, Liverpool.
1912 Parkin, Miss A. B., 3, Cairns Street, Liverpool.
1903 Tattersall, W., D.Sc., The Museum, Manchester.
1910 Tozer, Miss E. N., Physiology Laboratory, University, Liverpool.

C UNIVERSITY STUDENTS' SECTION.

President : Miss Robbins, B.Sc.

Secretary : Miss Clarke.

Treasurer : Mr. Daniel.

(Contains about 35 members.)

D HONORARY MEMBERS.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du brocadéro, Paris.
Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.
Claus, Prof. Carl, University, Vienna.
Fritsch, Prof. Anton, Museum, Prague, Bohemia.
Haeckel, Prof. Dr. E., University, Jena.
Hanitsch, R., Ph.D., Raffles Museum, Singapore.
Solms-Laubach, Prof.-Dr., Botan. Instit., Strassburg.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr. In Account with W. J. HALLS, Hon. Treasurer. **Cr.**

1912, Oct. 1st, to Sept. 30th, 1913.	£	s.	d.	1912, Oct. 1st, to Sept. 30th, 1913.	£	s.	d.
To Teas and Attendance at Meetings	3	11	6	By Balance from last Account	7	6	4
,, Lanternist	0	7	6	,, Subscriptions	18	18	0
,, Messrs. Tinling & Co.	40	0	0	,, Associate Members	2	2	0
,, Hon. Secretary's Expenses	2	7	6	,, Student Member	0	5	0
,, Hon. Librarian's Expenses	3	7	2	,, Subscriptions in Arrear	12	12	0
,, Cheque Book	0	0	10	,, Subscriptions in Advance	3	3	0
,, Bank Commission	0	2	0	,, Sale of Volumes	8	1	0
,, Balance	3	0	0	,, Bank Interest	0	9	2
	£52	16	6		£52	16	6

Audited and found correct,

HENRY C. BEASLEY.

Liverpool, *October 2nd, 1913.*

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

INAUGURAL ADDRESS

ON

BERGSON'S PHILOSOPHY OF THE ORGANISM.

By J. JOHNSTONE, B.Sc., President.

One only realises by attempting it how very difficult it is for a naturalist to discuss, in a broad manner, the large unsolved questions of his science. This is because our methods are still essentially descriptive, and because what some people have called the "mere cataloguing of organisms and of their structure and habits," occupies so much of our attention that we have little time and inclination for more abstract studies. One feels that our description of the organic world should be as complete as we can make it, and that it is quite certain that many generations of investigators must deal with the concrete things of biology before a really satisfactory philosophy of the organism can be foreshadowed. It is probably no easier for the physiologist, occupied with the application of the methods of physics to his descriptions of the functioning of the organism to attempt to weld together his results into a general treatment of the nature of life. Physics has advanced so rapidly along its own lines towards a rational conception of the universe that it is well-nigh impossible for the working naturalist to acquire such a knowledge of its concepts as will enable him to discuss thoroughly the fundamental problems of biology from the standpoints of physico-chemical science. It is not surprising, therefore, that philsophical enquiries of this kind should usually have come from outside the circle of professional biologists, and one may argue that this is as it should be, and that it is not our business to initiate such discussions.

It is, however, our duty to examine these discussions critically when they have been made by others, and it is from this point of view that I invite consideration, by working biologists, of M. Bergson's speculations, or at least of so much of them as appeal directly to us. It is, of course, quite impossible to deal with all the philosophy of the "Creative Evolution." Much of it is frankly metaphysical, and it is the tradition of our science to look coldly on such discussions. Bergson has been compared by Sir E. Ray Lankester to a man "looking in a dark room for a black cat which isn't there." Now all this sort of criticism is quite beside the mark. Even if we could avoid such metaphysical constructions in biology as the "force of heredity," Mendelian factors," "biophors," "living substance," "determinants," etc., we should not wish to do so. For many minds, perhaps to some extent for all, speculation beyond the bounds marked out by the positive results of scientific investigation is unavoidable, and we are impelled towards it whether we will or not. I suggest, then, that we frankly abandon ourselves to this mode of enquiry, and that those of us who like may salve our consciences by premising that however fascinating it may be it is not science.

Now it is not at all difficult to summarise briefly Bergson's philosophy so far as it concerns us as biologists. It is, however, necessary to take some liberties with his general line of argument which is, in some respects, rather too subtle for easy reproduction in brief. Generally speaking, philosophies of the organism suggested during the last century have been either mechanistic schemes, or such as involve the conception of finalism: that is to say, life and evolution in general have been regarded as the working out of a process which includes only the concepts of physics—matter and energy; or they have been regarded as the working out of a plan or design immanent in nature. The difference at first sight seems to be profound, but it disappears on close analysis, for in either scheme everything is given. The conception of mechanism is simple and clear for we start with matter and energy, and natural law, and from this everything in evolution works out by itself, so to speak. Finalism involves an anthropomorphic idea—that of a purpose to be worked out, of the assembling together of elements or parts which already exist so as to form a construction which is that of the plan or design. In the one case we look backwards, in the other forwards.

In either scheme we project outwards into nature the structure of the human mind, availing ourselves of the "categories of the understanding," substance, causality, unity, multiplicity, individuality, spatiality, and so on. If knowledge were attainable only by the working of the intellect we should be restricted to a mechanistic theory of the universe, but psychological analysis shows that this is not the case. Intelligence is only one of the results of the evolution of consciousness; side by side with it we have an intuitive knowledge of things; and intellect or reasoning alone, since its object is not primarily speculative, but practical, brings us to philosophical deadlocks. Intelligence operates by substituting concepts for the perceptions which we base upon sense-impressions, and then by subjecting these concepts to the operations of the categories of thought. But we have distinct intuitions for which we are unable to form clear intellectual notions. We can see and feel motion but we cannot conceptualise it. We can see and experience continuity or curvature or duration, but of these things the mind can form no clear concepts. If we think of the motion of a material particle over the space *a* to *b*, we will find that we can only imagine it moving from the one point to the other by supposing it to be, in succession, at each of a great number of intermediate points. If we try to conceptualise continuity we will find that we can treat it only by breaking it up into an infinite number of discontinuous states. What we call mathematical time is really a succession of natural events. The unit of time is the day, or interval between two successive transits of a fixed star. We can live through, or experience this interval, but we can only conceive it by breaking it up into sub-intervals, or seconds, which are the intervals between the successive swings of a pendulum of a certain length. And we must proceed in the same way if we try to conceptualise the time-interval of a second. In short, our concepts of motion, continuity and time involve only our concept of space, but that we intuitively realise all these depends on the fact that we endure. If we feel that one thing happens after another, that a kettle takes three minutes to boil, for instance, that is because we have endured throughout this succession of simultaneous events—the successive positions of the hands of the clock and the temperature of the water. The duration of an organism is the continual accumulation of its experience.

All this is quite clear and capable of detailed proof. It is no practical inconvenience to us now that we should be unable to represent intellectually parts of our actual experience, but we had to wait for the invention of the methods of the infinitesimal calculus and find ways of replacing our intuitions of motion and time by concepts of space, in order practically to circumvent these disabilities of the intellect. In all the practical affairs of life, therefore, the failure of intelligence to correspond exactly in its operation with intuition does not matter.

But in pure speculation the adherence to rigidly intellectual results has left us with the legacy of a notion of universal mechanism.

Physics, which is a much more complete science than biology, has proceeded to its great achievements by a method of infinitesimal analysis, and then by one of re-integration. What I mean by this statement is that physics has decomposed the universe into an assemblage of material bodies almost incredibly different in properties. Then it has reduced these to molecules, and each molecule to a combination of some of about one hundred different elementary kinds of matter—or chemical atoms. But the atoms themselves have been dissolved, so to speak, into something immaterial. Further, since space is traversed by radiation, both it and the atoms are replaced by an immaterial continuous medium—the ether—so that the universe has become a continuum or rather a continuous flux, and electrons and atoms and radiations are only states of this flux.

Out of this continuum our perception has carved the images of material bodies, molecules, atoms, electrons, etc. But our perceptions arise only when there is the possibility of deliberate action on the part of the organism. A reflex action, or more generally one which has become so habitual that it is performed automatically, is performed without consciousness, or at least it is not necessarily accompanied by consciousness, and we may think of what we call instinctive acting in the same way. But when we may act in response to some sense-impression or stimulus, and at the same time may refrain from acting, then that form of consciousness that we call our perception arises; and pain may even be regarded as that peculiarly vivid state of consciousness which is experienced when we are unable to turn some persistent stimulus into motor activity. We think of perception in this way: a stimulus falling upon a receptor organ is transmitted along an afferent nerve tract to the brain, and there are alternative paths for it. There is hesitation, deliberation, and finally choice, and the stimulus is transmitted along the efferent, motor path chosen and sets up some movements. The deliberation and choice of a path during the intermediate members of this series constitute our perception, with of course all other mental operations, comparison with the results of experience for instance. Perception then arises from our power of acting deliberately on our environment, that is to say, it accompanies the efforts made by the organism to acquire mastery over inert matter. All our science then, that is to say all our knowledge of the universe arises, not from speculative thought but as the preception that attends our action on the universe. We think intellectually in order that we may act; and when we speak of a material universe consisting of molecules and atoms and energy and radiation, we are speaking of a continuum which has been cut up along the lines which indicate our actual or potential powers of action. The intellect has thus evolved space and materiality, or rather space and materiality are the same thing as the evolution of intelligent acting, and are relative to the manner of working of the intellect. But intelligence is not all, for we find by psychological analysis that we act and think intuitively, that is we know things and do things otherwise than by a process of pure reasoning; and though our knowledge is mainly intellectual, it is, nevertheless, surrounded by a fringe of intuition. Mechanism and materiality and space are then only what our intelligent acting have isolated from the absolute of which we are parts, and these concepts are enough so long as we think only to act on inert matter. But in seeking to probe into the nature and origin of life we have to seek also for something which corresponds to so much of the absolute as cannot be conceptualised, that is something which cannot be described in terms of space and matter and energy, the only terms with which the intellect deals.

The argument then is that our concept of mechanism is only that of the manner in which the intelligent acting of man cuts up the universe and it does not necessarily afford a complete description of nature. If then we find that pure mechanism, that is to say, the concepts of physical science, fail to describe the phenomena of the organism we feel obliged to search for a new conception of life. It would not be enough merely to say that we are ignorant, and hope for the further development of physics, and the application of the results so obtained to the study of the organism. We see that intellect itself, which is the same thing as mechanism, is only a part of the evolutionary process.

Let us assume, then, that matter and energy are all, and let us attempt to describe the organism in terms of those notions, seeing if our description and that of physical science agree. Now science, so far as it is quantitative and deals with equations and inequalities, is based on the two laws or principles of thermodynamics, and it may be regarded as a test of the validity of a physical result that it should conform to those laws. The first law is that of the conservation of energy, and this states that the sum of energy which is contained in a system isolated from all others remains constant. If it becomes accumulated in one part of the system it must necessarily be reduced by a corresponding amount in some other part.

Energy is not necessarily this power of doing work: for us it is not necessarily causality, for although the sum of energy in a physical system may remain constant, the sum of causality may, indeed generally does, undergo decrease. This leads us to the consideration of the second law of thermodynamics, and for the purpose of our discussion this principle is of vastly greater significance than the first law. In its most general form, as enunciated by Clausius, it says merely that the sum of a mathematical function called entropy tends continually to increase. It can be stated in a more general manner by saying that all the natural processes studied by physics are irreversible and we can most clearly understand this by considering the working of a dynamo. If we cause the machine to revolve, that is supply a certain amount of mechanical energy to it, a current of electricity is generated, and the amount of this current should theoretically be equal to the energy of the mechanical motion supplied. If now we stop the machine and supply a current of electricity to it equal in amount to that already received the dynamo becomes a motor and begins to supply mechanical energy, and the amount of this should theoretically be equal to the energy supplied to the machine when it worked as a dynamo. That is to say it is perfectly reversible and transforms mechanical energy into electricity and *vice versa.*

This perfect reversibility would only exist if we could make a machine with perfectly rigid parts, which revolved without friction, which both conducted and insulated electricity perfectly. As a matter of fact the parts of the machine are not quite rigid, there is friction, its wires conduct electricity with a loss due to imperfect conductivity and insulation; all this leads to loss in such a way that mechanical friction is transformed into heat, imperfect conductivity into heat, and so on. The result of these conditions is that in all transformations of energy effected by a physico-chemical mechanism some of the energy is dissipated in the form of heat which is then radiated off to surrounding objects. Let us suppose that the solar system is an isolated portion of the universe: it is not, in fact, but we make it such by supposing that it receives just as much energy from the rest of the universe as it radiates off. In this system the energy which can be utilised is that radiated off by the sun, and part of that contained in the motions of the separate parts of the system. Solar energy is directly available in the form of oceanic and atmospheric circulations, and indirectly as the potential energy of coal and vegetation. The kinetic energy of the sun, moon and earth is again available in the form of tidal circulations. These processes, the contraction of the sun, the possible generation of energy by atomic disintegrations, the differential movements of the earth, moon and sun are all irreversible. When we make use of energy from any of these sources, loss is incurred; and the energy thus lost inevitably appears as heat which tends to become uniformly diffused throughout the system by conduction and radiation. A time must ultimately come, therefore, when the energy of the sun will have been dissipated as heat and when a state of equilibrium between planets, satellites and sun will have been attained, so that tidal effects will cease. The amount of energy still contained in the solar system will be enormously great, but it will be unavailable energy, for it will exist in the form of uniformly distributed heat, and as the kinetic energy of moving bodies in a state of equilibrium.

It does not matter how minutely we analyse the physical processes of the universe, the result is the same. The tendency is always for energy of every kind to become transformed into heat and for this heat to become equally distributed. We thus find, from actual experience, that there is an universal tendency towards the degradation of energy. It does not matter how big we make the universe so long as it remains finite: this ultimate uniformity of energy-distribution must some time be attained. The picture that we form of the universe is therefore that of a clock running down, or of a weight falling, and of an inevitable cessation of all becoming. Every natural process involving a transformation of energy leaves an indelible imprint somewhere on the universe and the state of the latter becomes permanently altered.

Now if the universe is everywhere the theatre of purely physical processes—and as long as we remain physicists we have no right to assume anything to the contrary—then nothing is more certain than the truth of this conclusion. There is nothing metaphysical in it for it simply represents the results of our experience. Yet nothing is more certain than that this conclusion is erroneous. For the human intellect is incapable of conceiving beginning and we are compelled to assume an infinitely long duration of the universe. It does not matter how slowly the growth of entropy takes place—there has been infinite time to draw upon for the attainment of complete energy dissipation. Nevertheless all the characteristics of the universe are those of diversity, and every star that we see is a focus from which energy is being radiated. We have to conclude then that the second law of thermodynamics is not universally true: that there are tendencies in existence unrecognised by physics which counteract that of the growth of entropy;

or else that the whole problem is a transcendental one. Now we are by nature disinclined to "give it up" in this way, and so we are forced into metaphysics.

But we have also to note that physicists impose limitations on the scope of the second law. In the first place it applies only to material masses within certain limits of size: really it is valid only when we consider particles of the size of the "differential elements" of the mathematician, that is particles which are very much smaller than material bodies which we can experiment with, but very much larger than a single molecule—which contain in fact very great numbers of molecules. It is only when the masses considered are very small that the methods of mathematical physics apply; and on the other hand the physical treatment of individual molecules would lead to entirely different results. The results of thermodynamics are, in fact, statistical ones, and in speaking of the properties of molecules we really speak of their mean properties—that is mean kinetic energy, mean free paths, and so on. Further, the great physicists, such as Clerk Maxwell and Kelvin, have expressly excluded living bodies from the operation of the second law.

If then we are to adopt a mechanistic theory of life, we must show that the processes of the organism conform to both laws of energetics. Now there can be no doubt that the law of conservation does so apply. It is possible to study the metabolism of an animal by measuring the energy value of the substances eaten by it during a certain period, and also that of the substances excreted during the same experiment. We find a deficiency, for less energy is contained in the egesta than in the ingesta, but this deficiency is made good by the mechanical work done by the animal, and by its heat loss during the experiment, and the difference from the theoretical result is less than the errors of the experiment. We may conclude then that all energy processes occurring in the organism are conservative ones.

But does the second law also apply? It is immediately evident that it does not apply in all the strictness that we can see in inorganic processes for the fraction of energy degraded is always very much less than in a purely physical process: a fact which we express by saying that the organism, considered as a machine, is very much more economical than any physico-chemical mechanism that we can construct. A comparison between an electric glow lamp and a phosphorescent organism brings out this contrast very clearly, for in the latter chemical energy is transformed into light without first of all passing into the form of heat. Shall we conclude, then, that the law of energy dissipation does not apply to the organism? If we consider only the highly specialised metabolism of the warm-blooded animal we receive little support for this conclusion for this metabolism is that of the type of a heat-engine. Certain food-stuffs, carbohydrates, fats and proteids, substances of high chemical potential—or high energy value—are ingested and undergo transformation into carbon dioxide, water and urea, that is into substances of low chemical potential or low energy value. The energy difference is represented partly by the work done by the animal, and partly by the heat radiated off and contained in the egesta. That is to say the changes are just those of a Carnot cycle, energy being drawn from a source of high potential and passing into an energy sink at low potential. Energy is dissipated during the cycle, but the amount so degraded is very much less than in the heat-engine. Now the metabolism of the warm-blooded animal is less economical than that of an organism need be, for it has to adapt itself to varying physical conditions and has, as far as possible, to maintain an uniform type of metabolism. But even so it is more economical than a heat-engine, and there can be no doubt that the cold-blooded animal is still more economical. The tendency in the organism is therefore for energy transformations to take place without degradation.

But in the green plant we see a process which seems to be essentially different from that of the animal. In this case the source of energy is solar radiation, and substances of low chemical potential—water, carbon dioxide and simple nitrogen compounds, such as nitrate—are transformed into substances of high chemical potential—carbohydrates, oils and proteids. This process is difficult to compare with that of the animal. It presents a likeness to a reversed Carnot cycle in that energy passes from a state of low to one of high potential. There is no transformation of chemical potential energy into mechanical energy; or at least this is minimal, being represented only by such movements in the plant as the ascent of the sap in trees against gravity; the movements of tendrils, etc., and the internal circulation of protoplasm in the cells. There is little heat production, except perhaps in a brief phase of the process of germination of the seed—at any rate this loss of energy is minimal. On the other hand, there is a continual accumulation of energy in the form of the substance of the plant. Now just how this transformation of carbon dioxide and water into carbohydrate occurs seems still to elude the plant physiologist. We usually say that the energy necessary is absorbed from the ether, that the plant is in fact an ether-engine, a conclusion which ought to lead on to the thermodynamical investigation of the process in terms of the concept of radiation pressure. But we must not conclude that carbohydrate synthesis is essentially or primitively a process of this nature, for we have the case of the nitrifying bacteria which synthesise carbohydrate in darkness, and in the absence of a chlorophyll mechanism. And, generally speaking, we must not conclude that in the accumulation of energy by the organism we have a process which involves simply an absorption of radiant energy, for an analogous synthetic process is to be seen in the fixation of atmospheric nitrogen by certain forms of bacteria. It is indeed possible to say that, in the case of the bacteria found on the roots of leguminous plants, the energy necessary for the synthesis is derivable from the metabolism of the plant, but then we have nitrogen-fixing organisms living in the open.

When we speak of life in general we are obliged to cease to distinguish between individual organisms, and we must regard its general tendency as that of the total mass of animal and vegetable life contained on the earth. Looking broadly at the distinctions between animal and plant we see that the latter is characterised by torpor and immobility, and by its tendency to accumulate energy in the shape of chemical compounds of high potential. The animal, on the other hand, is characterised by the possession of a sensory-motor system, and by its tendency to form compounds which exist in its tissues in a state of "false equilibrium": most of its metabolic processes have for their object the formation of these so-called "explosive" compounds, which become stored in its muscle fibres, and then more or less suddenly decomposed with the production of energy. This energy is liberated along almost infinitely variable paths in the higher animal, the mechanism employed being that of the sensory-motor system. Now these distinctions are not absolute ones any more than are the morphological distinctions between plants and animals. The zoospores of the Algae possess at least the rudiments of a sensory-motor system and are highly motile, and purposeful movements may be carried out by the higher plants. On the other hand, synthetic processes occur in the animals, and these, as in cases of parasitism, may exhibit torpor and immobility. Further, in the cases of symbiotic relationships of plant and animal, we see what might be regarded as indications of a primitive coalescence of both sets of tendencies, or at least we see the possibility of their co-existence in the same organism.

The general characteristics of life as we know it are therefore (1) the slow accumulation of energy by the transformation of compounds of low chemical potential into others of high chemical potential; and (2) the sudden transformation of these high potential compounds into low potential ones, and the regulation of the mechanical energy thus liberated by a sensory-motor system of mechanisms.

If we have to give a definition of life it must be one employing these facts of experience. Now we see at once that here we have something in the nature of a mechanism, but it is a mechanism which is difficult to describe in terms of the concepts of thermodynamics. Let us try to think of life in this way:—the metabolic processes of the organism in general, that is, its energy transformations, are represented by two phases (1) compounds of low potential—carbon dioxide, water and nitrate are built up into compounds of high potential—carbohydrate, oils and proteid, and work is done *on* the organism, the requisite energy being absorbed from the ether in the form of solar radiation. This is the plant phase. (2) Compounds of high potential—carbohydrate, fat and proteid are broken down, re-synthesised, and again broken down into compounds of low potential—carbon dioxide, water, and (ultimately) nitrate, and work is done *by* the organism in the form of movements controlled by its sensory-motor system. This is the animal phase.

That is to say, the organism, considered as a physico-chemical mechanism, may be compared with the imaginary mechanism known to physics as a reversible Carnot heat-engine. But the natural processes known to physics belong only to the positive half of the Carnot cycle: in them energy falls from a state of high to a state of low potential as in the metabolism of the animal. The reverse process, corresponding to the metabolism of the plant, in which energy passes from a state of low to a state of high potential is only conceived by physics, or can only be approximated to by operations directed by human intelligence. Further, the transformations studied by physics occur necessarily under conditions which lead to enormous waste, that is, the energy which should appear as work done becomes dissipated as unavailable heat at uniform low temperature; whereas the transformations studied in the metabolism of the organism proceed with so little loss of available energy that one may say that this waste tends to vanish. Therefore, the second law of thermodynamics does not necessarily apply to the organic mechanism while necessarily applying to the inorganic one.

I have assumed that in the metabolism of the organism the energy necessary for the construction of carbohydrate from water and carbon dioxide is absorbed from radiation. Now while this is the case with the green plant it is not apparently the case with the nitrifying bacteria which do essentially all that the green plant does in the absence of light. Where, then, do these organisms obtain the energy necessary for this transformation? In attempting to answer this question, we return to the consideration of the waste or unavailable energy which is the product of all physico-chemical processes. This energy exists in the form of low-temperature heat, that is, in the motion of the individual molecules of the substance into which unavailable energy passes. When the mechanistic physiologist speaks of this molecular motion, it is the mean motion of all the molecules of which he speaks: he adopts the statistical concept of molecular movement handled by the mathematical physicist, but unlike the latter does not note that the study of the individual molecules is also a legitimate subject for enquiry. Yet he is far more familiar than the physicist with the phenomena of Brownian movements; and the treatment of the individual rather than a statistical mean of individuals is also more familiar to him than to the physicist. Is it not strange, then, that the enormous significance of the Brownian movements should have been suggested by the physicists and not (to my knowledge) by the physiologists?

In a liquid containing particles exhibiting Brownian motion what we observe is the motion of the particles under the impacts of the molecules of the liquid. These molecules are moving at greatly unequal velocities and when the particle is small it continually happens that groups of molecules hitting it on one side have altogether greater momentum than those which hit it on the other side, with the result that it is pushed in the direction in which the molecules of greatest kinetic energy are travelling.

Are there organisms small enough to be affected by the impacts of individual molecules, or small groups of such? Most assuredly there are, for the Brownian motion of bacteria in a liquid is a sight familiar to us all, and we are pretty certain that ultra-microscopic organisms exist, while mechanistic biology has even postulated the existence of vital units, or biophors, consisting of relatively few molecules. If then these organisms, bacteria, or ultra-microscopic bodies, are able to utilise the kinetic energy of molecules moving at velocities greatly above the mean, we have a source of energy for the chemical transformations effected by the nitrifying bacteria. That these organisms should do so is not only conceivable but the question is one for experimental enquiry. If, for instance, we could show that in an insolated growing culture of nitrifying bacteria the temperature of the culture were to fall, we should have an indirect proof. But then we should show clearly that the second law of thermodynamics does not apply to the organism, and that by the processes of life entropy can be destroyed.

Now all this consideration of the metabolism of the plant and animal with reference to the laws of thermodynamics has been necessary to show that the conception of the organism as a physico-chemical mechanism fails, and that close analysis of vital processes makes it fairly certain that the functioning of plant and animal cannot be described solely in terms of the concepts of matter and energy employed in experimental physics. A concept peculiar to biology must be established, and thus we are led to the consideration of the vital impetus of Bergson, or the entelechy of Driesch. It is fair to state here that perhaps most biologists will hesitate to admit this necessity. I have followed, in the main, the arguments of Bergson, but younger biologists should note that these have been expressly characterised by Sir E. Ray Lankester as "worthless and unprofitable matter," and of interest only to the student of the aberrations and monstrosities of the human mind. The biology of the latter half of the nineteenth century was characteristically mechanistic (or materialistic). How powerful then must have been the impress left upon the minds of those educated during this period, when all the far more significant developments of the first decade of our own century have failed to remove this impression!

Let us assume now that the functioning of the organism in general consists in the relatively slow accumulation of energy, and in the relatively rapid liberation of this energy in controlled movements, and that while these processes are purely mechanistic ones, there is some tendency in the organism which gives them a direction different from that which we study in inorganic processes. We have now to consider what is the meaning of evolution. Why has life developed along a multitude of diverging lines rather than in one unilinear series? If we think of the total mass of organisms in comparison with the mass of the earth, we are almost startled by its incredible paucity. The surface of the land is covered by a film of vegetation of the most extreme tenuity, but which is, nevertheless, of greater mass than that of the animal life associated with it. The sea, when compared with the land, probably contains a greater quantity of life beneath each unit of surface, but even here the volume of the organisms is surprisingly small when compared with that of the water in which they live. The range of temperature of which we have experience covers several thousands of degrees, but the manifestations of life are only completely displayed within a range of less than 100 of these degrees.

We know about 100 chemical elements, but the physical substance of organisms is composed almost entirely of about half a dozen of these elementary substances. Does not all this mean that the vital tendency finds resistance from matter? It is impossible that all that it implies can be manifested in one material aggregation; and in the face of this resistance, this inability to influence completely energetic happening, the vital impetus has undergone dissociation.

Evolution has consisted therefore in the splitting up of the multiple bundle of tendencies which we call the vital impetus. Obviously the main cleavage consisted of the separation of plant and animal modes of metabolism. We have only indications of the possibility of the co-existences of these in the same organism, and everything points to the conclusion that in the physical conditions characterising our earth the accumulation of energy was incompatible with its expenditure. After this scission animal life became directly dependent on that of the plant. Numerous other main cleavages occurred on both the plant and animal sides, and we are not directly concerned here with the nature of these splittings. We think of them, in a way, as determined mechanically, each of them an experiment with the object of getting the better of inert matter, and most of them unsuccessful experiments. Judging success by the widest possible distribution over the earth, and the power of living amid the most diverse conditions, we see that three great groups of organisms have become dominant ones: the green plants; the arthropods culminating in the Hymenoptera and ants; and the vertebrates culminating in man.

In this latter cleavage we see the separation of two modes of acting—instinct and intelligence. Without doubt it is the development of these, rather than the diversity of physical structure, that indicates the main tendency along the two diverging lines of evolution. This statement implies that the difference between instinct and intelligence is profound, and indeed one can hardly study these two modes of acting without feeling that this is the case. I am aware that very much indeed has been written with regard to the evolution of instinctive acting, but it may be suggested that the formidable difficulties that attend all such hypotheses indicate that the problem is in itself a pseudo-problem. Is it not clear that we can make no real distinction between the organic functioning of an organ and the instinctive use of an organ? The first act of a newly born mammal is to draw a deep breath, and we do not hesitate to describe this action as simply the organic functioning of the muscles and nerves of the thorax, diaphragm, etc. Its next act is probably to suckle the breasts of its mother and this act which involves the same muscles, with some others, we incline to call instinctive. Yet is there any clear distinction between them? Is it not that our ingrained mechanism compels us to think of an organ in the same way as an artificial tool, the use of which has to be discovered and learned, and which we use at first imperfectly and then perfectly? Ought we not rather to think of the evolution of a bodily organ as that of the evolution both of its structure and functioning? That a dog should be able to swim instinctively may be explained on the principles of lamarckism or natural selection, but is it not more probable that the use of the limbs for progression through water was at all times in the evolution of the animals that led up to the carnivora the same thing as the existence of the limbs? Instinct, on this view, is the inborn knowledge of things which is implied in the possession of bodily organs structurally adapted to act on things. We must regard it as not necessarily accompanied by that which we recognise in ourselves as consciousness.

Intellect, on the other hand, we must regard as the evolution of something essentially different, the inborn knowledge of relations which we call the "categories of thought." We inherit these ideas of substance, space, causality, etc., and in virtue of them know the relations between things rather than the things themselves. It is true that we also possess an intuitive knowledge of things, but this we share in common with the lower animals, though perhaps to a less extent. Our knowledge of the relations of things, that is of natural law, enables us to cause things to act on each other; in the end it has enabled us to use tools. The perfect adaptability of the bodily tool to the purpose for which it evolved we replace by the imperfect adaptability of the artificial tool—the difference is that between the flight of the bird and that of an aeroplane. In the former case the bodily tool is a perfectly but a specifically acting one, in the latter case the tool is at first clumsy and imperfect. But in its construction perception, that is the association of intellectual processes with sense-impressions, arises and with this our peculiar intellectual consciousness, that is, our conceptual knowledge of the universe.

We cannot fail to see that what we recognise in ourselves as perception also exists, to some extent, in the lower animal acting for the most part instinctively. But just as all our knowledge of morphology demonstrates that clearly-cut distinctions of form do not exist, however much our classifications suggest them, so we have to recognise that intelligence and instinct always co-exist in the animal. Whatever cleavages have occurred in the process of evolution: however much the vital impetus has become dissociated into groups of tendencies, these cleavages are not absolute ones. Something of the synthetic metabolism of the plant remains in the animal, so much indeed in some of the lower organisms that we find it difficult to say to which category they may belong. Instincts are not the inevitable automatic actions they ought to be if they were pure, but we find that they become modified during the experience of the animal exhibiting them.

Among the mainly intelligent actions of man instincts also appear, and the indubitable use of tools among the typically instinctive insects has been observed. We recognise that the vital impetus meets with opposition in the conditions of our earth; that all of its tendencies cannot be manifested in the same organism; and that dissociation has occurred, different tendencies obtaining development in different groups. But whatever parts of the complementary tendencies can be transmitted, without detriment to the fullest development of the one or more appearing in the evolutionary line, are transmitted, so we find intellect appearing as a bright nucleus in a faint nebulosity of instinct, and *vice versa*. And indeed our study of structure shows us the same kind of predominance of one type of form, but the persistence of others as well.

The picture of evolution which we thus obtain is that of the appearance of a vital tendency for material and energetic transformations to take directions other than they do in what we term inorganic phenomena; and for the almost simultaneous splitting of this tendency into components. The cleavage of life into plant and animal most probably occurred about the same time as life appeared on our earth; and on the animal side all the main phyla were probably marked out in tendency from the first. The picture that our mechanistic notions of phylogeny afford is, on the other hand, that of a tree, of one main stem branching into two, and of the repeated branching of these until we reach the terminal twigs represented by one species. Now palæontology, which alone might show which of these pictures is the true one, will probably never do so; and it cannot be urged that morphology gives any unequivocal evidence. Everywhere in schemes of descent we have had to postulate annectant forms, hypothetical "proto-vertebrata," "proto-mollusca," etc. Does it not indicate that most of our main groups of organisms—vertebrata, arthropoda, mollusca, echinodermata, etc., are truly collateral to each?

Yet we see along the course of these main lines the evidence of branching, the actual transformism of species, innumerable divergences, progressions, retardations and extinctions. Each of these is an adventure so to speak, an attempt, mostly unsuccessful, to get the better of inert matter. In its details the study of evolution is the description of this process of transformism, and we are, if anything, rather embarrassed by the number of such descriptions, or hypotheses of evolution. If we are to accept the notion of a vital impetus meeting with opposition, inserting itself, as Bergson says, into the interstices of inert matter, and dissociating itself, then the process of transformism is immanent in life. Terrestrial organisms are in their very nature organisms undergoing transformism, and the problem of evolution is the same thing as the problem of the nature of life.

But our hypotheses of evolution are mechanistic ones. If living matter exists then evolution results from the working of chemical and physical laws. In the process of natural selection variability is the datum. Certain slight variations from the normal confer on some of the individuals of a population a greater mastery over the environment and these variations become transmitted, and being repeated in the progeny of the individuals displaying them, they become accumulated. A species is the accumulation of these variations. It is the effect and the variations are the causes, or putting it more precisely the species is a function of certain independent variables: a way of stating the thesis which brings it into line with the physical concept of causality. If, on the other hand, we chose to regard lamarckism as a working hypothesis of transformism we have a description which is just as clearly mechanistic. Changes produced in the somatic tissues of the animal during its lifetime and by its environment produce changes in the germinal tissue, and these germinal changes lead to the variation of the progeny from the form possessed by the parent. Now a thinker, following up the notion of a factor in life other than that of mechanism, will naturally hesitate to accept either natural selection or lamarckism as a competent cause of transformism. Bergson, impressed by the dogmatism of modern biology, refuses to accept the evidence of lamarckian inheritance; and reasoning from the occurrence of convergent characters in independent lines of descent, refuses to accept natural selection, or at least refuses to accept either hypothesis as in itself competent to produce transformism. I do not propose to examine this argument against natural selection, which appears to be the part of Bergsonism with which most biologists are familiar: it can easily be shown to be erroneous. Nor need we examine the argument against lamarckism: it, too, is familiar. The idea of natural selection is so admirably clear and simple that we cannot willingly abandon it, while the very persistence with which lamarckian hypotheses arise, and the equivocal nature of the results of experiment, warn us that it may very well be a factor in transformism. And, above all, one feels that the whole question of the nature of the process of evolution turns upon the formulation of a theory of heredity.

It is probably safe to say that the only such theory which we need consider is that of Weismann. Let us admit that the central idea of this hypothesis—that of the continuity of the germinal substance—is, generally speaking, an eminently sound one. The species, rather than the individual, is truly the organism. The germinal substance does not *act*. Secluded from the environment, the vicissitudes of the latter do not (in general) affect it. It must grow, and in that respect must come into relation with an environment, but the soma makes this environment inasmuch as body after body converts so much of its medium as is necessary into an internal germinal environment unchanging throughout generation after generation. But variations in the soma reflect and magnify variations in the germ. How then do the latter arise? We trace them back to the time when the distinction between soma and germ did not exist and when the organism, being *both* soma and germ at the same time, acted upon its environment and was impressed by it. The individuals composing a metazean species contain a germplasm of multiple origin, and consisting of very numerous elements. Variability arises from the permutations and combinations of these elements brought about by amphimixis.*

This hypothesis is so simple and clear that at first we hardly hesitate to accept it. But its application to the results of experiment so robs it of this pristine simplicity that we begin to doubt its truth. We see that

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* We admit the logical strength of Weismann's later hypothesis of germinal selection. But the difficulties arising on analysis of this conception are very formidable.

it is bound up with a highly conjectural hypothesis of variation, and sooner or later in all discussions of the nature of transformism we come to the question of the origin of variations—the most fundamental of all. Let us state this problem in its most difficult form. If we examine the thousands of ova produced by an animal, we will find that in respect of any one measurable character there is more or less deviation of each ovum from the imaginary mean. Let us admit that some of this deviation may be accounted for in various ways: there remains a residue of variations which have all the appearance of spontaneity, of arising *de novo.* But our reason rebels against the assumption that these differences have no causes, and immediately we are faced with the tremendous problem of the causes of variations. Now is it not possible to argue that this is only a pseudo-problem? We know that a great number of the ova arise from the division of one mother-cell. They ought to be identical, we think, and if they are not identical there should exist causes why they vary from each other. But why are we forced to postulate this identity? It is again because our intellect is essentially practical. Its object is to act on things, to manufacture in short. Let us think of a minting machine making coins and we see that practical reasons dictate the desirability of these coins being identical in form and weight. So we make more and more perfect minting-engines, each of which turns out sovereigns more nearly identical than the last one. In the limit we conceptualise a machine which makes coins absolutely identical with each other, and our actual varying sovereigns differ from each other because the action of the machine in each operation is not quite the same. Then we apply this concept of a mechanism, an artifice of practical and not of speculative value, to the reproductive process. If intellect and life were the same we should have no other alternative than this. But our analysis of consciousness and acting shows that intellect is itself only a part of the result of evolution, Must we not conclude then that variability is something given, and incapable of further description and that the concept of causality does not apply to it? Then each variation is something new and evolution is creative.

Thus, by more than one way we approach a conception of life which contains more than the working concepts of physical science. We see that a theory of knowledge is, as Bergson says, the same thing as a theory of life. Biology itself shows that the evolution of consciousness has proceeded along two lines, one leading to intuitive knowledge of our environment—a knowledge which we first of all *feel* simply, but which we may attempt with more or less success to describe and communicate; and another which has led to intellect—a knowledge of our environment which we attain by action, but only after action: this is the knowledge that we express and communicate by language. Whoever tries to analyse the way in which he investigates will surely see this—that discovery is the result of "guesses," that hypothesis after hypothesis arises in his mind with all the appearances of spontaneity, and that intellectuality merely tests these speculations. It is easy, too, to see that intellect is the product of action, that we know our environment intellectually only after we have acted on it, and that this kind of knowledge is that of the manner in which we can produce change in that part of the universe accessible to sense-impressions. It is almost a commonplace way of expressing this to say that science —that is intellectual knowledge—is essentially useful knowledge; that there is no positive scientific result which is not of utility to man. The whole history of science goes to prove this.

Intellectual knowledge is therefore necessarily knowledge of a mechanism. Of all tests, that of the power of prediction is the surest test of the truth of a scientific proposition, and of all knowledge that which enables us to predict is the most useful. But this kind of knowledge is that of something where everything is already given, where the future is only a function of that which already exists, a future re-arrangement or assembling of elements now arranged in a different manner. It is, therefore, the knowledge of determined events only—of matter and energy and natural law. If it were capable of describing all that our sense-impressions enable us to feel it would be sufficient, but we have seen that our mental concepts fail to describe fully our perceptions. But our life is mainly that of a struggle with the inorganic environment, and practical things are of vastly more importance than speculative knowledge. And so, whether we will or not, the tendency to force all that we can observe into the modes of thinking marked out by our modes of acting becomes almost irresistible; and therefore just because we can experiment upon it, and because our experiments have utility, we conceive of life as mechanism.

Indeed all that we can possibly discover about it intellectually must be mechanistic: we shall never describe it in any other way than in terms of matter and energy. Neither do we describe mathematically a curve in any other way than as a series of tangents: we can make the tangents infinitesimal in length so that the figure which they make is indistinguishable from a curve, nevertheless it is not a curve. We can make a series of photographs of a motion and by combining these by a cinematograph produce all the appearance of the motion, but the picture is something entirely different from the reality. We can subject the structure and functioning of the organism to such infinitesimal analysis. The structure decomposes to organs, tissues, cells, nucleoplasm, cytoplasm, biophors, micellae, etc.; and the functioning decomposes to colloidal reactions and all the rest of it; but in this is there anything different from the building up of the curve from infinitesimally short straight lines, or the moving picture of the cinematograph from motionless pictures? When we say that the processes of the organism are only those of matter and energy, we forget that physics has already traversed the path which biology still treads, and that after its infinitesimal analysis of the universe it has recomposed its energy, corpuscles, atoms, molecules and particles in a homogeneous ether which eludes description and which retains nothing of the description of matter and energy except motion. And motion is just that aspect of experience which mathematics had failed to conceptualise. Physics has returned, in a way, to an intuitive understanding of the universe, to a metaphysics, if we like, and it expresses this only by the construction of intellectual "models." Is it not clear that biology must yet attempt this integration of its analytical results? And should we not emulate the modesty of the physicist and think of our physico-chemical descriptions of the organism only as intellectual models?

It is strange that those who adhere to the view of life as a mechanism should usually avoid its definition. They manage somehow or other to conceive of consciousness as a product of energy transformations, a process in which nevertheless all the energy remains, *as well as* the consciousness, a truly remarkable result! But having achieved this miracle the rest should be easy. The functioning of the organism involves fundamentally the accumulation of energy, the establishment of phases of false equilibria, and the release of the energy in controlled movement. That is the result to which our study of the organism as a mechanism leads. But does it not widen immensely our conception of life in general? It is not necessary that life should be tied down to plastic carbon and nitrogen compounds, to limy and siliceous skeletons, to cytoplasm and chromidia. It is a non-essential incident that the life which we know is manifested in this way. Everything that we know of the universe shows us irreversible processes and energy undergoing degradation, and the experimental results of physics point unequivocally to the progress of this energy degradation towards the ultimate cessation of all becoming. The most general view that we can take of life is that of a physical process in which the counter-tendency to degradation is exhibited, in which entropy is diminished. There *must* exist such a tendency, but how is it to be expressed? The only physical image that we can shape is that of a clock spring winding itself up or of a weight rising. But we have also the image of Maxwell's sorting demons. If we were able to control the motions of individual molecules we should arrest the growth of entropy. Now our postulate of a vital impetus is just as hard to imagine. It is not any form of energy, but rather the possibility of conferring *direction* on the course of energetic changes. It is difficult to understand, but no less so is the physical concept of the ether of space. There is nothing in life that is not in material and energy transformations, but in the organic the direction of these energy transformations is the reverse of that in the inorganic; and in some way or other the consciousness of the organism is to be associated with this interruption, or reversal of tendency, it is useless to speculate how.

There is something *naïf* in the discussions as to the nature and origin of life, of which modern mechanistic biology has been so prolific. Life we are told must have originated, since the conditions on our earth were certainly such as precluded the possibility of organisms. But is it not possible dimly to imagine life as existing in *any* conditions where energy transformations could take the opposite direction from those that we see in inert matter? If living substance passes into non-living substance, as we indeed daily see it pass, the opposite change must be postulated: so Weismann teaches. But all the experience of physics is that energy transformations are irreversible and if we base our physiology purely on physics, the transition of the living into the non-living affords no reason for postulating that the reverse transition may occur. Professor Schäfer sees no reason to doubt that the formation of living substance is possible at the present day apparently by the employment of methods which will be those of physics and chemistry. But all these methods involve processes the *direction* of which is the opposite of those which characterise an essential phase of the cycle of energy changes in the organism. How, then, could their employment produce a substance behaving like the cells of a plant? In all these suggestions we see the influence of the false analogy of the organism with the physico-chemical mechanism. The problem is, of course, not in any way a transcendental one; that is, it is not inconceivable that living substance might be "artificially" produced. But we ought to see clearly that such a "synthesis" would be effected in some other way than by the methods of physical chemistry. Intellectually we must remain ignorant of the nature of life, since the human intellect is bound down to the consideration of space and materiality. But the fringe of intuition that surrounds intellect is part of the movement of life, and through intuition we may attempt to know life.

FIG. I.—IN FRONT OF THE BIOLOGICAL STATION, PORT ERIN, IN A STORM.

[From a photograph by Mr. Edwin Thompson.

THE

MARINE BIOLOGICAL STATION AT PORT ERIN

BEING THE

TWENTY-SIXTH ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE.

The year that is just ending completes the first decade of our occupation of the new Biological Station and the second decade of our work at Port Erin. In the Report from our Curator, Mr. Chadwick, which is given below, will be found some interesting statistics in regard to the use made of the Station by students and visitors during the ten years of its existence.

The year 1912 has been probably the most successful that we have had, from the point of view of scientific work and instruction of students. The extension that was effected a couple of years ago by the addition of the research wing (see figs. 2 and 3) has been most fully occupied, and further accommodation for research workers is urgently required.

The number of workers has doubled in the last six years, and the following figures show the recent rapid increase:—

1907	35	1910	57
1908	38	1911	60
1909	40	1912	74

The usual Easter vacation courses in Marine Zoology were carried on during April under the guidance of Mr. Douglas Laurie and Dr. Dakin, and, in addition, Professor Harvey Gibson again held a course of lectures and practical work on Marine Algæ for students of

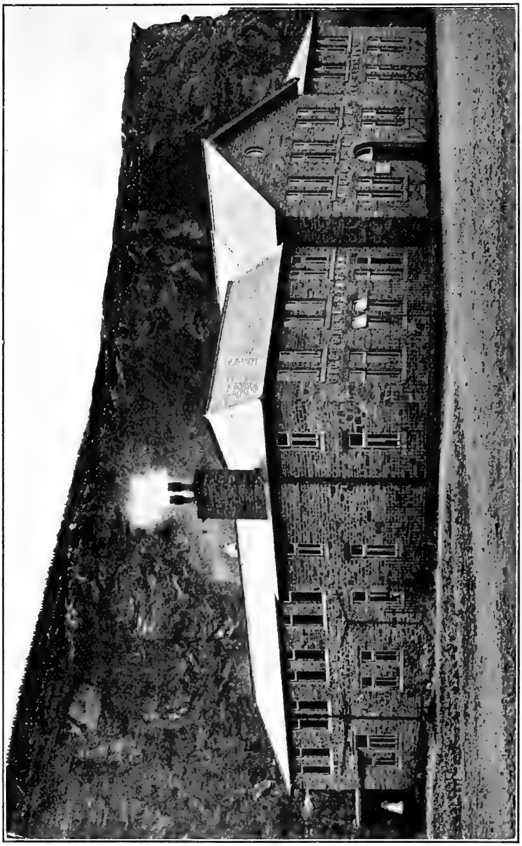

FIG. 2. The Port Erin Biological Station from the North East.

[From a photograph by Prof. F. J. Cole.

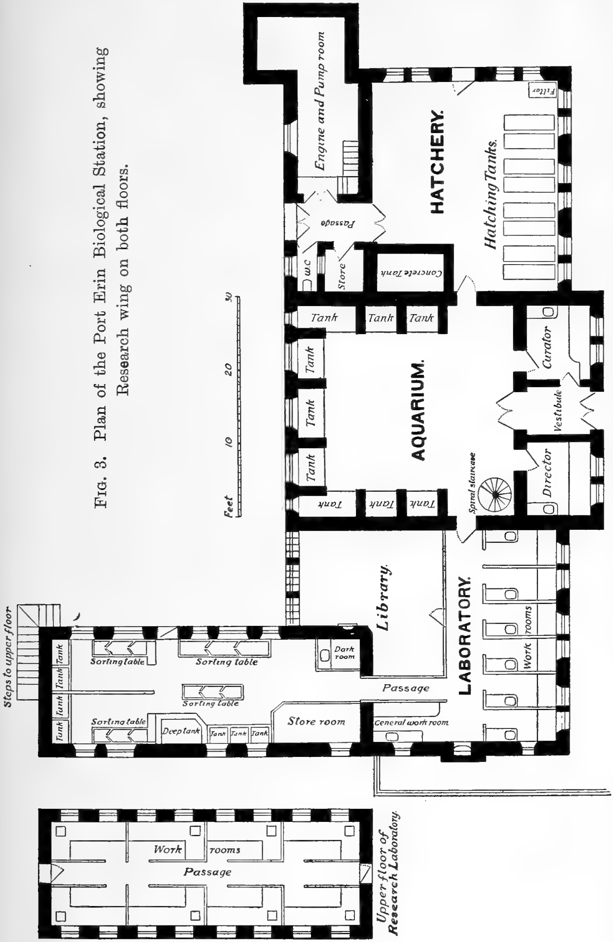

FIG. 3. Plan of the Port Erin Biological Station, showing Research wing on both floors.

Botany. Other senior students comprised a group from Manchester, a party, under Professor Cole, from University College, Reading, and a few from University College, London. Altogether, amongst researchers and senior students, six different Universities or Colleges were represented in the Laboratory during the greater part of April.

Among structural improvements effected during the past year may be noted :—(1) a new partition wall (fig. 4) built across the larger spawning pond, so as to divide off a small area at the shallow end for lobster rearing; (2) a pair of new outside concrete tanks put up for a research on the attachment of Algae, etc., to various surfaces, to

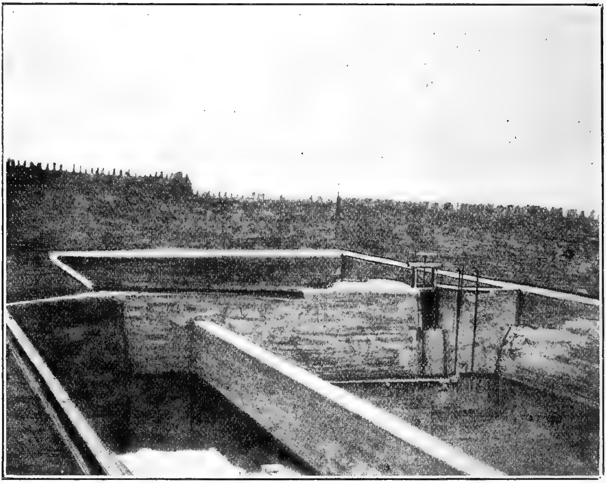

FIG. 4. View of the Spawning ponds when empty, to show the new wall subdividing the larger pond.

be undertaken by Prof. Harvey Gibson and Dr. Reynolds Green, and (3) the alteration and equipment of the large top room in the west wing to form a bio-chemical laboratory for Prof. Moore's research on the sea-water.

As on previous occasions, I shall first give the statistics as to the occupation of the "Tables" during the year, then will follow the "Curator's Report," and the reports that have been sent to me by various investigators on the work they have done, and, finally, I shall describe some of the researches in which I have been myself taking part.

THE STATION RECORD.

Upwards of seventy researchers and students have occupied the Work-Tables in the Laboratories for varying periods during the year, as follows:—

Dec. 18th to 22nd, 1911, and Dec. 27th, 1911, to Jan. 8th, 1912.	Dr. Dakin.—Buccinum
Dec. 27th, 1911, to Jan. 8th, 1912.	Professor Herdman.—Official.
Dec. 28th, 1911, to Jan. 3rd, 1912.	Miss R. C. Bamber.—General.
Jan. 1st to 8th, 1912.	Mr. H. G. Jackson.—Eupagurus.
Jan. 2nd to 8th.	Miss C. M. G. Lewis.—Buccinum.
March 29th to April 18th.	Mr. G. Storey.—General.
March 30th to April 22nd.	Miss R. Robbins.—General.
,,	Miss C. M. G. Lewis.—Echinoid Embryology.
,,	Mr. R. J. Daniel.—General.
,,	Miss F. M. Firth.—General.
April 1st to 20th.	Miss A. Kyffin.—General.
,,	Miss D. A. Stewart.—General.
April 1st to 22nd.	Miss H. M. Duvall.—General.
,,	Miss F. Tozer.—General.
April 3rd to 15th.	Miss M. L. Hett.—General.
,,	Miss M. Tribe.—General.
,,	Mr. R. G. Gale.—General.
April 3rd to 22nd.	Miss R. C. Bamber.—General.
April 3rd to 15th.	Professor F. J. Cole.—Educational.
,,	Mr. Malpas.—General.
,,	Miss O. Attride.—General.
,,	Miss J. Freeman.—General.
,,	Mr. H. L. Hawkins.—Echinodermata.
April 3rd to 23rd.	Professor Herdman.—Plankton.
,,	Mr. W. Riddell.—Plankton.
,,	Mr. H. G. Jackson.—Eupagurus.

April 4*th to* 19*th.*	Miss M. Knight.—Marine Algæ.
,,	Miss B. Norbury.—General.
,,	Miss E. Lewis.—General.
,,	Miss C. M. P. Stafford.—General.
,,	Miss O. G. Ellams.—General.
,,	Miss D. E. Payne.—General.
,,	Miss E. Edmondson.—General.
April 4*th to* 22*nd.*	Mr. W. H. Evans.—General.
April 5*th to* 22*nd.*	Mr. J. Erik Hamilton.—General.
April 6*th to* 22*nd.*	Mr. C. L. Burt.—Educational.
April 10*th to* 22*nd.*	Mr. W. A. Gunn.—General.
April 10*th to* 20*th.*	Mr. E. Holden.—General.
April 10*th to* 16*th.*	Professor H. Bassett.—Hydrography.
April 10*th to* 20*th.*	Miss M. Stoddart.—General.
,,	Miss K. Clegg.—General.
,,	Miss J. Gregory.—General.
,,	Miss O. Payne.—General.
April 10*th to* 22*nd.*	Miss U. Little.—General.
,,	Miss L. Higson.—General.
,,	Miss M. Udall.—General.
,,	Miss F. Robinson.—General.
,,	Miss A. Garside.—General.
,,	Miss G. Clegg.—General.
,,	Miss J. Upson.—General.
,,	Miss H. Coburn.—Marine Algae.
,,	Miss G. Wilkinson.—General.
,,	Miss M. Calvert.—General.
,,	Miss M. Stubbs.—General.
,,	Miss A. Kay.—General.
,,	Miss E. Smith.—General.
April 10*th to* 19*th.*	Mr. W. J. Waterhouse.—General.
April 10*th to* 20*th.*	Dr. W. M. Tattersall.—Educational.
,,	Mr. E. Shann.—Educational.
,,	Miss E. M. Blackwell.—General.
April 11*th to* 20*th.*	Professor R. J. Harvey Gibson.—Educational.
,,	Mr. G. E. Johnson.—Nematoda.
,,	Mr. F. J. Meggitt.—General.
April 11*th to* 22*nd.*	Mr. R. D. Laurie.—Educational.
April 11*th to* 23*rd.*	Prof. B. Moore.—Nutrition of Marine Animals.
,,	Mr. E. Whitley.—Nutrition of Marine Animals.
,,	Mr. E. S. Edie.—Nutrition of Marine Animals.
April 11*th to* 19*th.*	Miss E. Beardsworth.—General.
,,	Miss E. Morgan.—General.
,,	Miss M. McWilliam.—General.
,,	Miss N. A. Potter.—General.
,,	Miss A. M. Dawson.—General.
April 11*th to* 22*nd.*	Miss D. M. Little.—General.
,,	Miss Latarche.—General.
April 15*th to* 20*th.*	Mr. J. C. Waller.—General.
May 17*th to* 22*nd.*	Mr. V. H. Mottram.—Physiology.
May 25*th to* 28*th.*	Professor Herdman.—Official.
July 15*th to August* 24*th.*	Mr. W. A. Gunn.—Lobster Culture.
August 5*th to Sept.* 16*th.*	Mr. E. S. Edie.—Nutrition of Marine Animals.
August 5*th to Sept.* 2*nd.*	Prof. B. Moore.—Nutrition of Marine Animals.
August 5*th to Sept.* 16*th.*	Dr. H. E. Roaf.—Physiology of Invertebrates.
August 13*th to* 17*th.*	Professor R. J. Harvey Gibson.—Marine Algæ.
August 13*th to* 26*th.*	Mr. V. H. Mottram.—Physiology.
August 23*rd to Sept.* 7*th.*	Mr. E. Whitley.—Physiology.

Sept. 12*th to* 20*th.*	Professor Herdman.—Plankton.
Sept. 12*th to* 23*rd.*	Dr. Dakin.—Buccinum.
Sept. 12*th to* 16*th.*	Mr. Julian Huxley.—General.
Nov. 16*th to* 19*th.*	Professor Herdman.—Amphidinium.
,	Professor B. Moore.—Analysis of Sea-water
Dec. 14*th to* 16*th.*	Professor B Moore.—Analysis of Sea-water.

The "Tables"* in the Laboratory were occupied as follows:—

Liverpool University Table :—

Professor B. Moore.
Professor R. J. Harvey Gibson.
Professor Herdman.
Dr. H. E. Roaf.
Dr. Dakin.
Mr. R. D. Laurie.
Mr. H. G. Jackson.
Mr. V. H. Mottram.
Mr. E. S. Edie.
Mr. E. Whitley.
Mr. W. H. Evans.
Miss Latarche.
Mr. W. A. Gunn.
Mr. C. L. Burt.
Miss E. M. Blackwell.

Liverpool Marine Biology Committee Table :—

Mr. G. Storey.
Miss M. L. Hett.
Miss M. Tribe.
Mr. R. G. Gale.
Mr. W. Riddell.
Mr. E. Holden.
Mr. J. C. Waller.

Manchester University Table :—

Dr. W. M. Tattersall.
Mr. E. W. Shann.
Miss A. Kyffin.
Miss D. A. Stewart.
Miss O. Payne.
Miss M. Stoddart.
Miss K. Clegg.
Miss J. Gregory.

Birmingham University Table :—

Mr. G. E. Johnson.
Mr. F. J. Meggitt.

University College, Reading, Table :—

Professor F. J. Cole.
Miss O. Attride.
Miss J. Freeman.
Mr. H. L. Hawkins.
Mr. Malpas.

The following students of Liverpool University occupied the Laboratory for periods varying from a

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*Since the new research wing has been added several distinct apartments are generally available for the accommodation of the investigators assigned to any one of the University "Tables."

fortnight to three weeks during the Easter vacation, and worked together under the supervision of Professor Harvey Gibson, Mr. Laurie and Dr. Dakin:—

Miss R. C. Bamber.
Miss C. M. G. Lewis.
Miss R. Robbins.
Miss F. M. Firth.
Miss H. M. Duvall.
Miss F. Tozer.
Miss M. Knight.
Miss B. Norbury.
Miss E. Lewis.
Miss E. Morgan.
Miss A. M. Dawson.
Mr. W. J. Waterhouse.
Miss C. M. P. Stafford.
Miss O. G. Ellams.
Miss D. E. Payne.
Miss E. Edmondson.
Miss U. Little.
Miss L. Higson.
Miss M. Udall.
Miss F. Robinson.
Miss A. Garside.
Miss M. McWilliam.
Miss D. M. Little.
Mr. J. Erik Hamilton.
Miss G. Clegg.
Miss J. Upson.
Miss H. Coburn.
Miss G. Wilkinson.
Miss M. Calvert.
Miss M. Stubbs.
Miss A. Kay.
Miss E. Smith.
Miss E. Beardsworth.
Miss N. A. Potter.
Mr. R. J. Daniel.

Amongst professional visitors to the Biological Station during the past year may be noted Professor Julian Huxley and H.M. School Inspectors, Mr. H. Ward and Mr. Vesey.

Curator's Report.

Mr. Chadwick reports to me as follows:—

"The accommodation afforded by our laboratories has again been taxed to the fullest extent by a further increase in the number of researchers and students who availed themselves of it during the Easter vacation. The museum gallery was again utilised, and the large room above the fish hatchery, hitherto used as a store-room for oceanographical apparatus and fishing gear, had to be requisitioned and furnished as a temporary laboratory for the use of Professor Moore and his coadjutors in their research on the nutrition of marine animals.

"For about ten days during the Easter vacation no fewer than 65 persons were engaged on work in the laboratories, and the Curator had considerable difficulty in supplying their numerous and varied wants. The work done followed closely on the familiar lines of previous years; and the students who participated in the excursions to the caves near the Sugar Loaf Rock and other collecting grounds in the neighbourhood of Port Erin (see fig. 5 for the appearance of such a party), arranged and led by Professor Herdman, Professor R. J. Harvey Gibson, Professor Cole, Mr. Laurie, Dr. Dakin, Dr. Tattersall and Mr. W. A. Gunn, found ample material with which to occupy the hours spent in the laboratory.

FIG. 5. A party of Students on a collecting expedition listening to a demonstration by the Professor.

[Photo by Dr. W. J. Dakin.

"Evening lectures were given by Professor Cole, Professor Herdman, Professor Moore, Dr. Dakin and the Curator; but this excellent feature of the vacation work is susceptible of still further development in the future.

"The weekly lessons and demonstrations in Nature Study given to the boys from the local Secondary School, mentioned in last year's Report, were maintained with regularity until March, when the Curator was obliged to suspend them, in anticipation of the Easter vacation work. They have now been resumed, and, with improved appliances, will be continued throughout the winter. Lantern lectures were given to large parties of pupils from local and Douglas elementary schools on various dates during the early Spring.

"The plankton collections in the bay, twice each week, have been made by the Assistant Curator with regularity throughout the year. The only faunistic records that call for notice are the occurrence in Port Erin Bay, on September 18th, of a specimen of the Fuller's Ray, *Raia fullonica*, a species not hitherto recorded by the L.M.B.C., and of the cuttle-fish, *Sepia officinalis*, in Manx waters. Two clusters of eggs of this species were found attached to a creel in the neighbourhood of the Calf Island; and quite recently a young fisherman brought to the Curator the 'bone' of what must have been a large specimen which he had picked up on the beach at Glen Meay, a few miles north of Port Erin. The occurrence of the eggs excited more than ordinary interest amongst the local fishermen, none of whom had seen them before.

"The number of visitors to the Aquarium during the year—14,132—shows a substantial increase of nearly a thousand compared with last year. The record day of the year was August 14th, when 436 persons paid for admission. The last copies of the second edition of the Guide to the Aquarium were sold before the end of July; and the third edition, in which improvements and additions in text and figures appear, was immediately placed on sale. Seven hundred and eighty copies in all were sold, making an increase of 80 compared with the sales of the previous year. The Curator still occasionally receives from persons resident in far distant parts of the Kingdom orders for copies, in terms which show that the little work is regarded as possessing permanent value, especially to teachers in elementary schools.

"The success of the hatchery work was seriously impaired this year by the prevalence of disease amongst the spawning plaice, and the number of fry set free—1,667,500—was very disappointing. The work of the spawning pond and hatchery was efficiently undertaken by the Assistant Curator, who thoroughly skimmed the pond almost every day during the spawning season and made the most of the greatly reduced quantity of eggs.

"The numbers of eggs collected and of larvae set free during the past season were as follows:—

Eggs collected.		Date.	Larvæ set free.		Date.
54,600	...	March 9 to 16	50,000	...	April 1
37,800	...	,, 18 to 21	31,500	...	,, 4
224,700	...	,, 22 to 26	150,000	...	,, 5
130,200	...	,, 27 to April 1	115,500	...	,, 13
230,200	...	April 2 and 3	185,000	...	,, 16
161,800	...	,, 4 and 5	137,300	...	,, 17
237,300	...	,, 6 and 9	208,000	...	,, 18
225,700	...	,, 10 and 11	204,700	...	,, 20
428,300	...	,, 12 to 17	374,500	...	,, 22
120,700	...	,, 18 and 19	83,000	...	,, 24
195,400	...	,, 20 to 24	120,000	...	May 4
18,800	...	,, 27 and May 1	8,000	...	,, 6
2,065,500			1,667,500		

"The young fish were, as usual, set free out at sea, off the S. and W. of the Isle of Man, by Professor Herdman from his yacht 'Runa.'

"The experiments in lobster culture were this year conducted by Mr. W. A. Gunn, of the Zoology Department of the University of Liverpool, and it is gratifying to be able to report much greater success than has hitherto been attained. Eighteen berried lobsters with ripening eggs were obtained from local fishermen, and from these 10,257 larvae (fig. 6) were hatched. Falling back upon the Curator's earlier experiments, Mr. Gunn used the Dannevig hatching boxes, and in these he succeeded in rearing 333 larvae to the fourth or 'lobsterling' stage. During the season 4,367 larvae in various stages of development, including all but a small number of the lobsterlings, were set free in the sea. Accidental stoppage of the circulation in one of the hatchery tanks unfortunately resulted in the death of a considerable batch of larvae which had reached the third stage; and cannibalism accounted for the disappearance of many others; but, taken as a whole, Mr. Gunn's results are encouraging and promise greater things in the future.

FIG. 6. Newly-hatched lobster larva.
[Photo by Mr. Edwin Thompson.

"The year 1912 completes the first decade in the history of our present building, and it has occurred to the Curator that a few words by way of retrospect may not be without interest to those who have supported, as well as those who have actually participated in, the work of the institution. Examination of the Station Records has shown that during the ten years 225 researchers and students have paid altogether 385 visits to the Station. The University of Liverpool has contributed by far the largest number, but that of Manchester has been represented every year by an enthusiastic, if small, contingent. The Universities of Cambridge, Birmingham, Leeds, Sheffield, and Edinburgh, and the University Colleges of London, Reading and Nottingham, and the Bedford College, London, have been represented, almost every year in the case of the two first named Universities, and a small number of private workers make up the list.

"The total number of visitors to the Aquarium during the ten years is 137,000. These figures make a striking commentary on the prediction of a prominent resident of Port Erin, who, when the building was in course of erection, told the Curator in confident tones that without a band the Institution would never be a success! The record of the attendance of visitors shows that even during the first year the Aquarium won for itself an assured position in the esteem of the large numbers who visit Port Erin in search of health and pleasure; and though the numbers have fluctuated somewhat from year to year, that position has been well maintained.

"The work of the fish hatchery has resulted in the liberation in the sea of nearly forty millions of young plaice (fig. 7) and a considerable number of lobster larvae. This branch of our work has been beset by many difficulties, in overcoming which much valuable time was spent during the first two or three years. The efficiency of the hatchery has now, however, been greatly increased by duplication of the pumping machinery; and the experience gained in the course of ten years' work affords solid ground for the confident hope of much greater success in the years to come."

H. C. Chadwick.

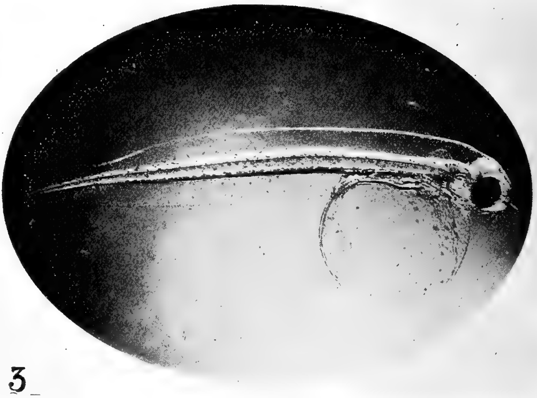


Fig. 7. Newly-hatched Plaice. Photo by Dr. F. Ward.

Other Reports on Work.

Professor Benjamin Moore, along with Mr. E. Whitley, Dr. W. J. Dakin, and Mr. E. Edie, has been carrying on an extensive physiological and chemical investigation, with the support of the Percy Sladen Trust, into the nutrition and metabolism of marine organisms. It is well known to biologists that Professor August Pütter, of Bonn, has recently put forward the view that marine animals cannot be nourished by the plankton or very minute living organisms suspended in the water, but are dependent for their food upon dissolved organic matter which is found, he states, in sea-water and is directly absorbed—the sea being thus itself a nutritive medium. Professor Moore has drawn up the following report upon the work carried on by his colleagues and himself in the Easter vacation:—

"Our work was commenced at Port Erin Biological Station in April, and was continued during the Easter vacation. This work was connected with the elaboration of new methods, and the testing of those methods which had been devised and used by Pütter and others, and it has already led to results which are fairly conclusive. A commencement has also been made upon the investigation of the respiratory needs of animals, which is most suggestive and has opened up new problems. The primary objects of all these investigations were:—

"1st, to determine the amount of organic carbon present in solution in the sea-water;

"2nd, to determine the amount of the same substance present in the plankton;

"3rd, to estimate the amount of organic carbon required per day by certain marine animals.

"The water used was, in some instances, collected and treated at a point some miles out in the Irish Sea, and our thanks are due to Professor Herdman for the use of his steam-yacht 'Runa' in connection with this part of the work. On other occasions the water was collected nearer shore, in Port Erin Bay or in the aquarium of the Biological Station.

"Apparatus was fitted up so that water pumped from the sea with considerable speed could be filtered first through the finest silk bolting cloth of the kind used in ordinary plankton nets, and then through a Chamberland filter which removed bacteria and minute plankton. The filtered water was analysed, as also the catches on the silk and the Chamberland filter.

"The results show conclusively that the amount of organic carbon present in the sea-water is almost negligible (lying well below one milligram per litre of water), and that Pütter's figures are very incorrect. It has also been shown that the amount of plankton normally present and distributed through the water is practically just as insufficient to provide food if the sea-water is merely filtered, as it comes, by a marine animal. Organic matter in solution and plankton together do not seem present in sufficient quantity for the nutrition of active marine animals, unless they hunt their food or frequent the zones where plankton is especially abundant.

"All the difficulties of the problem are, however, by no means solved by these preliminary experiments, and we hope in the course of the summer vacation to carry out an extension of the work and to undertake more detailed investigations on the respiration and metabolism of marine animals.

"The respiratory quotient in these lower animals appears to differ widely from that found in mammalia, and certain of them seem to be able to bear deprivation of oxygen for hours, and during this interval continue to form carbon-dioxide in almost undiminished quantity. With a normal supply of oxygen there are very great variations in the rate of oxidation in the different species made use of.

"A first paper on the subject has been prepared and was published in the Bio-Chemical Journal, Vol. VI, Part III, July, 1912."

Further work during the Summer vacation

corroborated and extended the above results. Estimations were carried out to show the demand for oxidisable food in various species of invertebrates, and it was found that while the plankton supply, as found generally distributed, might prove sufficient for the nutrition of such sedentary animals as Sponges and Ascidians, it is quite inadequate for active animals such as Crustaceans, Molluscs and Fishes. These latter are, however, able to seek out their food, and are not dependent upon what they may filter or absorb from the sea-water.

The relative output of carbon-dioxide as compared with intake of oxygen has been ascertained, and it is shown that complete oxidation of the food does not occur, the respiratory quotient lying well over unity in most cases. A metabolic basis to account for this peculiar respiratory condition is put forward in the second paper on this research, which is nearly ready for publication.

Mr. Gilbert E. Johnson, M.Sc., of the Zoological Research Laboratory in the University of Birmingham, sends me the following report upon his work while occupying the Birmingham University "Table" at Port Erin:—

"I spent about a week at the Laboratory during the Easter vacation, working on Nematodes. I was successful in my object of gaining some idea of the little-known group of the free-living marine forms and their distribution.

"I collected samples of material from as varied situations as possible round the shore, and found that the free-living Nematodes are almost ubiquitous. They occur in shore-sand, both wet and dry, on the undersurfaces of large stones exposed at low tide, in fine shingle between the weed-covered rocks in the Laminaria zone, among the small red and green seaweeds growing in both salt and brackish water rock-pools and attached to boulders just exposed at low tide, on the brown seaweeds (especially among the haptera), and with the animals picked from the walls of the caves and from the sides of the breakwater.

"The genera found were *Oncholaimus*, *Enoplus*, *Spilophora*, *Rhabditis*, *Plectus*, *Dorylaimus*, and a few others, which, owing to the meagreness of the literature on the free-living marine forms, I was unable to determine with certainty. Some of these genera are peculiar to salt water. The rest are found also in fresh water and on land.

"The majority of species, especially those more distinctively marine, were seen to be provided with adhesion glands at the tip of the tail. By means of these they are enabled to attach themselves to some suitable support and, probably, to maintain their position, resisting the force of the waves, which would otherwise send them adrift.

"Species possessed of eye-spots were not uncommon, though by no means so numerous as those not so provided. Both kinds, however, were constantly found in company.

"Nematodes were especially abundant in situations rich in organic débris. They were also numerous in certain localities where Diatoms were plentiful, as among the small red and green seaweeds growing in the rock-pools and attached to boulders just exposed at low tide. A number of individuals of the genus *Oncholaimus* were found to contain the frustules of Diatoms, all of the same genus *Fragilaria*, both in the oesophagus, down which they were passing, and in the intestine, where they were congregated. These Diatom-consuming Nematodes were found among tufts of *Corallina officinalis* in the rock-pools and in bunches of small filamentous seaweeds, such as *Polysiphonia,* which were growing epiphytically on *Fucus vesiculosus* and *Ascophyllum nodosum.* Bastian has recorded the similar occurrence of Diatoms in the intestine in the case of two other genera of Nematodes.

"The gall on the 'stems' of *Ascophyllum nodosum* caused by the attacks of *Tylenchus fucicola,* a near relative of *T. devastatrix,* the notorious Stem Eel-worm, was also found. This is the first gall made by a Nematode to have been found on seaweed.

"Some of the above observations formed the subject of a short letter which appeared in 'Nature' on May 30th."

Mr. V. H. Mottram, who has been researching at the Biological Station on the fats of fishes and of their food, sends me the following short report upon his work:—

"In May the fatty acids of the myotomes, the livers and the food of the spawning pond plaice were investigated, and in August those of plaice caught in the neighbourhood. As far as fatty acid metabolism is concerned, the plaice from the spawning pond showed no abnormality—they were closely comparable with those from the sea. The iodine values of the liver fatty acids ranged from 100 to 190—average about 150. Those of the myotome fatty acids were uniformly above 200—average 205; while those of the mussels were just below 200.

"The results are being published in detail in the 'Journal of Physiology,' and are already in the press."

Professor Harvey Gibson reports as follows:—

"During the Easter vacation a course of instruction on Marine Algae was given at the Station on the same lines as last year, and the course was attended by over twenty senior students from the Botanical Department of the University.

"Each day a certain area was selected in Port Erin Bay, Fleshwick Bay, or at Port St. Mary, from which Algae were collected and afterwards examined in the laboratory, careful lists of all Algae found in each area being made. In addition to this, short lectures on representative forms were given in the evenings. As a result of examination of the collections, together with those of last year, about fifty species have been identified as occurring in the area over and above those previously recorded.

"A paper on the Marine Algae of the district is now in preparation, which, it is hoped, will be published in the 'Transactions of the Liverpool Biological Society' at an early date.

"The following are some of the more noteworthy species added to the Marine Flora this year:—

CHLOROPHYCEAE—

Enteromorpha ramulosa.
,, erecta.
,, ralfsii.
Urospora penicilliformis.
,, bangioides.
,, flacca.
Chaetomorpha linum.
Rhizoclonium riparium.
Cladophora fracta.
,, gracilis.
Codium mucronatum.

PHAEOPHYCEAE—

Litosiphon laminariae.
Stictyosiphon griffithsianum.
Striaria attenuata.
Ectocarpus crinitus.
,, fasciculatus.
Isthmoplea sphaerophora.
Elachista stellulata.
Phyllitis fascia.
Chorda tomentosa.
Fucus platycarpus.
Dictyota ligulata.

RHODOPHYCEAE—

Porphyra leucosticta.
,, ciliaris.
Erythrotrichia carnea.
Actinococcus roseus.
Callymenia reniformis.
Rhodymenia palmetta.
Lomentaria rosea.
Nitophyllum gmelini.
Polysiphonia spinulosa.
Rhodochorton mesocarpum.
Rhododermis elegans.
Corallina rubens, f. corniculata.

"Specimens of Marine Algae were also collected at Peel, during the Summer vacation, by Miss M. Knight, B.Sc., and on Hilbre Island during the month of August by Miss H. Coburn, B.Sc. The latter collection included plants of *Catenella opuntia* bearing cystocarpia, a fruiting condition in this species which has very rarely been recorded."

During Easter, 1912, Professor Moore and his colleagues continued their researches on the glycogen and fats found in surprising quantities in the gonads of Echinus, the Sea-urchin, and the bio-chemical part of the work has since been continued in the University Laboratories at Liverpool by Dr. Adams and others. A paper on the results is now in course of publication, in which it is shown that throughout the period of physiological inactivity of the glands, storage products such as glycogen, lecithides and fats accumulate in as great quantities in the gonads as they are usually found in a metabolic organ such as the liver or hepato-pancreas of other species of animals. Even after a prolonged period of abstention from food in captivity, these stores are not appreciably drawn upon by the metabolism, which is reduced under such conditions to a very low limit. Under normal conditions of nutrition the amount of food consumed by the Echinus is many fold that required for the ordinary metabolic uses of the animal, and is stored up in the gonads for reproductive purposes. The amount of lecithides, fats and glycogen is approximately equal in the two sexes. The fats or oils are of a very unsaturated type, similar to fish-liver oils, such as cod liver oil. A large proportion of the dry weight of organic matter of the gonad is made up of these reserve foods or metabolic products.

Dr. W. J. Dakin, in addition to planktonic work bearing on Professor A. Pütter's views as to the nutrition of marine animals, was occupied during the Christmas and Easter vacations in finishing his investigation on the structure of *Buccinum undatum*, the large whelk. This work has since appeared as L.M.B.C. Memoir No. XX, illustrated by eight plates, and giving one of the most complete accounts that has yet been published of a Gastropod Mollusc.

Mr. W. Riddell, M.A., acted as my assistant in the plankton investigation during the Easter vacation. On taking up his new work for the Lancashire and Western Sea-Fisheries Committee he was succeeded as Research Assistant by Mr. Harold G. Jackson, M.Sc. Both these gentlemen rendered good service, and their work will be incorporated in the Sea-Fisheries Report during 1913. Mr. Jackson's further work consisted of a detailed investigation of the structure and habits of the common Hermit-crab, *Eupagurus bernhardus*, which it is hoped will be published as an L.M.B.C. Memoir before the end of 1912.

Mr. Riddell's further work at Port Erin dealt (1) with Polychæt worms, in which group he has a new record to announce, viz., *Castalia fusca*, dredged near the Calf Sound, and not previously found in Manx waters; (2) with the bacterial disease of the spawning plaice which he and Dr. Moore Alexander had found to be a septicæmia due to a bacillus (see Lancashire Sea-Fisheries Laboratory Report for 1911, p. 85). As a result of this discovery we have subjected our fish-ponds to a very thorough process of cleansing and disinfection in the hope of getting rid once for all of the troublesome micro-organism.

Professor Cole, University College, Reading, writes to me as follows:—"Our Port Erin party last Easter—the largest we have sent—consisted of seven workers, and included in addition two students from University College, London. Beyond having spent a very instructive and interesting time, which we are all anxious to repeat, there is nothing special to report. We made a number of injections and other preparations for the museum. We find Port Erin suits our purposes from all points of view, and the opportunities for geological and antiquarian, as well as biological, work are greatly valued. Most of our biological students take geology, and we are fortunate in being able to supply them with the necessary instruction in that subject. Our next Easter party will be larger still, and our College Council has increased its usual grant towards the expenses of the class."

Mr. Andrew Scott reports to me the following additions to the known Copepod fauna of the district which have been met with since the last list, published in the Twenty-first Annual Report:—

"*Itunella tenuiremis* (T. Scott). Two specimens of this Harpacticoid were found on separate occasions in the plankton collected in Port Erin Bay in 1911 and 1912. It is very slender and easily overlooked.

"*Clytemnestra rostrata* (Brady). A single specimen of this interesting form occurred in a bay collection taken on 24th December, 1910. It has been recorded from the South of England and the West of Ireland.

"*Oncaea minuta,* Giesbrecht. One or two specimens from the same collection as the last. It is very small and difficult to determine. The Port Erin specimens (female) measured 0·62 mm.

"*Oncaea subtilis,* Giesbrecht. In the same collection with the two previous species. It is quite distinct from the normal type of *Oncaea*, and can be readily recognised by its cylindrical and rather slender abdomen. The occurrence of these three species in a bay gathering is interesting, as they are generally regarded as oceanic forms, and probably indicates an unusual flow of Atlantic water into the Irish sea prior to their appearance. *Corycaeus anglicus*, Lubbock, recorded from Port Erin Bay in November, 1898, and in May, 1899, by I. C. Thompson, was also present in the bay gathering taken 24th December, 1910, and again on 13th February, 1912.

"*Kroyeria lineata*, P. J. van Beneden. In the hollows between the gills of male *Galeorhinus galeus*, the Tope or Toper, trawled on King William Bank off the North of Isle of Man, April, 1912. Males and females were not uncommon on specimens of that dog-fish landed at Piel by Captain Wignall of the Fisheries steamer "James Fletcher." This parasite is apparently confined to male fish—at any rate we have never come across it when examining females. It has hitherto only been recorded from the coast of Belgium (van Beneden) and the coast of Italy (A. Brian). No doubt the habitat of the parasite has something to do with the paucity of records. One requires to fold back the gill-rays one after another to find it.

"*Eudactylina insolens*, T. and A. Scott. Four specimens of this abnormal member of the genus were found on the gills of the Topers along with the *Kroyeria*. It resembles *Eudactylina acanthii* in some respects, but can be recognised by the incomplete segmentation of the thorax and the uncinate second pair of feet."

Mr. Scott also draws my attention to the absence of any record of the crab *Gonoplax rhomboides* (=*angulata*) in the Revised List of species recorded from the Liverpool Bay Area (Brit. Assoc. Meeting, Liverpool, 1896, and in Report V, Fauna of Liverpool Bay). He says:—"Its absence is evidently due to accidental omission, as Mr. A. O. Walker records it from Southport on the authority of C. H. Brown, on page 225, Report I, Fauna of Liverpool Bay. The late R. L. Ascroft, soon after I first knew him, told me that *Gonoplax* was occasionally captured between Blackpool and Southport by shrimp trawlers. I have a well-developed specimen that was taken in the shrimp trawl of the first Fisheries Steamer 'John Fell,' near Nelson Buoy at the entrance to the Ribble, on one of my first expeditions in the Irish Sea." This crab has also been found by Mr. Riddell off Maughold Head, Isle of Man, and also in the stomach of a Dab caught at Selker Lightship.

Dr. W. M. Tattersall, who was one of the occupants of the Manchester University table in the Easter vacation, has sent me this report on additions to the fauna:—

"I have to record the following species of Amphipoda and Isopoda as new to the L.M.B.C. district, as the result of collections made by Miss D. A. Stewart, of Manchester, Mr. Gilbert Storey, of Cambridge, and myself, at Port Erin during last Easter vacation.

"ISOPODA—

"*Apseudes hibernicus*, Walker. Several specimens, in black mud, under stones, at extreme low water mark, spring tides, on the shore below the Biological Station. Previously known only from the West Coast of Ireland at Valentia, coasts of Galway and Mayo.

"*Tanais cavolinii*, M.-Ed. Several specimens found by Mr. Storey, in old wooden piles from the breakwater, bored by *Limnoria lignorum*, Rathke.

"*Pleurocrypta porcellanae*, Hesse. Miss D. A. Stewart found two specimens of this species, parasitic on *Porcellana longicornis*. These are the first undoubted specimens of this form which have been recorded from British waters. I have myself (Clare Island Survey Reports, Part 43, 1912) recorded a Bopyrid from *Porcellana longicornis,* in which the males had the abdomen distinctly divided up into segments, whereas the males of the present specimens, as, indeed, of all species belonging to the genus *Pleurocrypta,* have the abdomen unsegmented. The Clare Island specimens probably belong to an undescribed species.

" AMPHIPODA—

" *Gammarus duebenii* (Lilljeborg). I found a Gammarid, which I take to be this species, very abundant in pools, which occur in crevices and hollows on the limestone shores at Scarlet Point. These pools are practically of fresh (rain) water, which may become slightly brackish at extreme high tides or during storms. Gnats were breeding in them freely at Easter, and numbers of water beetles were noticed. *Gammarus duebenii* was very abundant in every pool, but I am not aware that it has previously been recorded from this area.

"*Caprella acanthifera* (Leach). Mr. Storey collected two specimens among hydroids and sponges on the shores of the Calf of Man, in the Sound."

THE MINUTE LIFE OF THE SEA-BEACH.

In our last Report it was shown that certain greenish-brown patches on the sandy beach at Port Erin, a little below high-water mark, are caused sometimes by vast numbers of the active little Dinoflagellate animal known as *Amphidinium operculatum,* and sometimes by equally large quantities of various quiescent Diatoms—unicellular plants enclosed in delicate siliceous cases.

During 1911, the history of this alternation of two very different lowly organisms forming these coloured patches on the sand was as follows:—

April 7 to May 1	Amphidinium, and a few Diatoms
June 3 to July 22	Diatoms
Sept. 9 and 10	Amphidinium in abundance, Diatoms absent
Sept. 16 to 18	Diatoms
Oct. 2 to 26	Amphidinium in abundance, Diatoms absent
Oct. 28 to Nov. 1	No Amphidinium present
November 2	Amphidinium (3 small patches)

During the remainder of the winter no patches were found, but by the beginning of April *Amphidinium* had reappeared in force and monopolised the beach for a couple of weeks. It was then replaced by Diatoms for a few days, and in the latter part of April, 1912, the alternation took place no fewer than four times, ending with a couple of weeks in May, when neither organism was present. *Amphidinium* reappeared on May 15th, and was present more or less during the greater part of the summer, except in the comparatively few drier intervals of July and August, when it was absent. From September 14th onwards, when I returned to Port Erin after the British Association Meeting, it has again been present continuously in larger or smaller patches, and lately I have been able to examine in Liverpool living samples sent from Port Erin in tubes of damp sand, up to the last days of October. Mr. Chadwick reports to me that it was present during the first week in November and disappeared in the second. On November 18th I was again on the beach at Port Erin and found the coloured patches present and swarming with *Amphidinium.*

One of these *Amphidinium* patches, lying opposite the North end of a short length of low wall which fronts the middle of Port Erin beach (see fig. 8, at point marked x), has been remarkably persistent during recent months. Other patches on the beach come and go, but this one remains. There must, of course, be some reason for this—possibly environmental and connected with the drainage of water from the upper part of the beach during low tide—but we have as yet failed to determine

FIG. 8. Beach at Port Erin, showing Amphidinium patch at x.

it with any certainty. We are under the impression, moreover, that the *Amphidinium* patches are more prevalent during neaps than at spring tides. This might be the result of increased dampness on the beach when the tide is out, due to the sea-water in the sand not sinking so far below the *Amphidinium* level.

The history, then, of *Amphidinium* on the beach in 1912, so far as our observations show, is as follows. Some of the dates are only approximately correct:—

April 1—12	...	Amphidinium
April 13—15	...	Diatoms
April 16—20	...	Amphidinium
April 21—23	...	Diatoms
April 24—27	...	Amphidinium (traces only)

April 28—May 14	Neither
May 15—onwards	Amphidinium (more or less)
August (parts of)	Neither
Sept. 14—Nov. 9	Amphidinium
Nov. 10—14	Neither
Nov. 15—16	Amphidinium (small patches)
Nov. 17	None
Nov. 18—20	Amphidinium (several large patches)
Nov. 21—30	Traces and small patches only

Now another curious point—in all the recent gatherings, since September 14th, 1912, the individuals are found to differ considerably in shape, size, and some other minor points, from the *Amphidinium operculatum* we had been examining in such quantity at Port Erin during the preceding year. The new form (see fig. 9), while agreeing more closely with the genus *Amphidinium*

FIG. 9. *Amphidinium operculatum*, larger, elongated form prevalent at Port Erin in the autumn of 1912: *b* and *i* show intermediate characters; *m* and *n* are seen edgeways; *h* is an optical section to show that the pigment is peripheral leaving a clear centre; *g* is probably an immature stage.

than with any other described genus, approaches both *Gymnodinium* and *Spirodinium* in certain characters. It agrees with *Gymnodinium* in having the anterior part of the body relatively larger (see fig. 9, *e* and *l*), that is, the transverse furrow is further back than in the typical *Amphidinium operculatum* (see fig. 10, *i* and *l*). Then again, it suggests the genus *Spirodinium* in that the transverse furrow is curved so as to form an approach to the spiral form (fig. 9, *d* and fig. 10, *h*). On November 18th, I found that while most of the individuals were of the larger and more elongated form (fig. 9), a few of the older, short, broad form (fig. 10, *i* and *l*) were present along with various encysted and *Gymnodinium*-like forms (fig. 10, *a* to *g*), which are probably younger stages in the life-history of *Amphidinium operculatum*. The previous day (Nov. 17) when no discoloration was visible on the beach, a scraping of sand taken from the usual place showed under the microscope a very few active *Amphidinia* and a few Diatoms, and also some rounded stationary *Amphidinia*

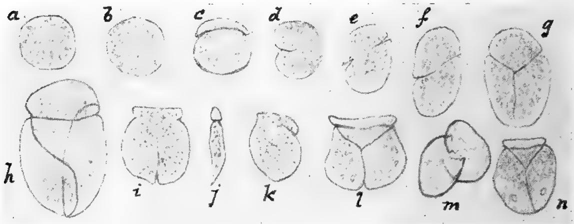


FIG. 10. Various forms of Amphidinium found on November 18th : *a* to *g* encysted and immature stages ; *h* and *i* larger and shorter forms for comparison ; *j* side view of *i* ; *k*, *l* and *n* stages of short form ; *m* a fission stage.

adhering to sand grains in hollows and crevices (fig. 11). It may have been these inconspicuous resting forms that gave rise to the vast swarms of the following day.

I am not of opinion, as yet, that this difference in the characters of our *Amphidinium* indicates more than a variation or "form" of the same species—possibly seasonal, or due to age, or nutrition, or some other environmental influence; and the existence of this variation does not, of course, affect the broad phenomenon of the striking alternation of the two very different kinds of organisms, the Diatoms and the Dinoflagellates, in vast quantities. It is quite possible that the changes of minute life on the beach are even more complicated than we have yet discovered, and that when no coloured patches are visible the sand is occupied by large numbers of ciliate or flagellate Infusoria. In some of our laboratory experiments we have noticed that as the *Amphidinia* died and disappeared, colourless Infusoria, which would not be visible to the eye in the sand, took their place as the most abundant organisms, but whether this happens also on the beach is not yet known.

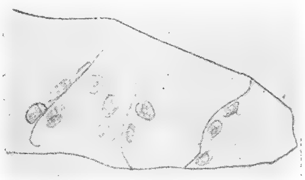


FIG. 11. Small quiescent Amphidinia adhering to a sand grain.

Although it may not be possible yet to give any detailed and precise explanation of the alternation, the facts seem to point to the probability that the cause of the phenomenon is a physiological one, and that the explanation may consist in showing that each organism in turn, in its life-processes or metabolism, exhausts or alters some essential constituent of the environment, so as to prevent its own continued existence, in quantity, at that spot, but leaves the ground suitable, or even favourable, to the physiological needs of the other set of competing organisms.

Possibly we have a similar phenomenon on a more extended scale in the now well-known seasonal and other variations in the plankton of the open sea, where during spring and summer, as we have shown by our work at Port Erin, the main constituent groups of organisms are Diatoms, Dinoflagellates, and Copepoda, succeeding one another in that order. Figures 12 and 15 on page 70 show a spring gathering of phyto-plankton (Diatoms) and a summer gathering of zoo-plankton (Copepoda), as seen under the microscope. Figure 13 represents the intermediate group, Dinoflagellata (to which *Amphidinium* also belongs).

In this connection it is interesting to see that Professor Benjamin Moore has recently discovered, in the course of his Percy Sladen Trust research at Port Erin into the Nutrition of Marine Animals, that there is a notable change in the chemical reactions of the sea-water round our coasts at different seasons of the year—no doubt in co-relation with the development of vast quantities of plankton organisms. In spring (April) the water, not only on the shore but also out in the open sea, is acid to phenol-phthalein, while in summer (August) it is distinctly alkaline to the same indicator. This change signifies an enormous conversion of carbon in the inorganic into carbon in the organic form—a turnover of colossal extent amounting to between 20,000 and 30,000 tons of carbon per cubic mile of sea-water. Or, if we think of the carbon as being present in the bodies of living organisms, then the weight of these organisms will amount to about ten times the above amount, viz., about 300,000 tons per cubic mile—or, if we imagine these organisms distributed along the deepest part of the Irish Channel, then they would occupy a strip of water about 10 miles long by one mile wide and 88 fathoms deep—all of which organisms have obtained their carbon from the carbon-dioxide present in the water in spring.

Professor Moore is continuing his observations upon the condition and changes of the sea-water monthly throughout the year.

The alkaline reaction of the sea to phenol-phthalein indicates, moreover, the absence of free carbon-dioxide. It thus follows that, during the summer, plants in the sea must obtain their carbon from the decomposition of carbonates or bicarbonates in the water—probably from these salts of magnesium—and not from carbon-dioxide as they presumably do in spring when the water gives an acid reaction.

Thus we are led from the observation of the minute organisms on the beach to some of the greatest problems in connection with the chemical and biological changes going on in the ocean; but it need not be thought by the young naturalist that he must necessarily adventure forth on to the high seas in pursuing his quest. Some investigators must, no doubt, do so; but there remains plenty of useful work to be done on the beach and in the laboratory in carefully examining with the microscope the various deposits, such as sand and mud, found between tide-marks, not once for all, but periodically, so as to determine the nature of the minute animals and plants, their relative abundance, and their variations, seasonal or otherwise, in quantity and character throughout the year.

The investigation has both scientific and economic importance. We know that some of these organisms, although so minute and individually insignificant, may exist in such quantities as to discolour the sands or the sea-water, and even give rise to plagues amongst shell-fish and other more directly valuable animals. Invasions of this kind, due to Dinoflagellata closely allied to our *Amphidinium*, are known to have appeared in the United States and on the Australian coast, and possibly elsewhere. It is work worthy of some of our younger botanists and zoologists who are skilful microscopists and have ready access to the coast throughout the year, to try to extend our knowledge of the characters, range of distribution, and life-conditions of some of these remarkable organisms. The marine Dinoflagellata not only present scientific problems to the field naturalist, the cytologist, the experimental biologist, and the bio-chemist, but also from their vast numbers and sudden changes are bound to have a great effect upon the metabolism of the ocean, and so upon the distribution and prosperity of our sea-fisheries.

Plankton Investigations.

The plankton work has been carried on in much the same way for the last five years, with the help of various Assistants, from the S.Y. "Runa" out at sea during the Easter and Summer vacations, and across Port Erin Bay in small boats during the rest of the year.

In all, about 400 samples have been collected from Port Erin and the neighbourhood during the year, in addition to those from other parts of the Irish Sea. A detailed account of the plankton results will be given, as usual, by Mr. Scott and myself in the Lancashire Sea-Fisheries Laboratory Report, to be published early in 1913, but we may give here the following preliminary statement in regard to the variations of the year 1912. There was a distinct Diatom maximum in April, largely composed of *Chaetoceras*, which was represented by eight species. *Chaetoceras debile* and *C. sociale* were the most common Diatoms in the spring months. A collection taken with the fine net in the Bay on April 29th measured 29·5 c.c. It was practically a pure phytoplankton. *Chaetoceras debile* was represented by 36 millions and *C. sociale* by 44 millions. The other Diatoms present were also in large numbers. *Lauderia borealis* was represented by 12 millions, and *Asterionella japonica* by 2 millions, and *Thalassiosira nordenskioldii*, which was so abundant and persistent in the spring of 1907 but comparatively scarce since, was represented by 4 millions. The occurrence of *Thalassiosira* in 1912 appeared to be rather spasmodic. In some collections chains of individuals were fairly numerous. In others there were very few. Some days it appeared to be common, on other days almost absent. The Diatoms became scarcer in May, but there was a distinct increase again towards the end of that month, due to the summer invasion of *Rhizosolenia*. In previous years, *R. semispina* was the abundant species, but in 1912 it proved to be comparatively rare. Its place was taken by *R. shrubsolei*. A fine net collection, taken in the Bay on 30th May, gave over 107 millions of *R. shrubsolei* and nearly 2½ millions of *R. semispina* (see fig. 16). Diatoms were scarce in July and August, but there was a marked autumn maximum during the last

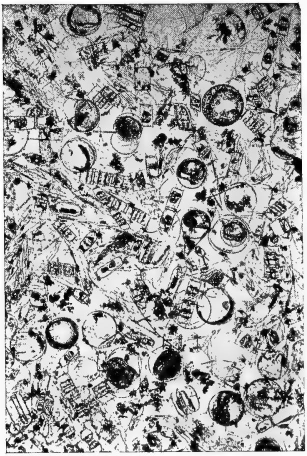


FIG. 12. Diatom Plankton, consisting mainly of *Coscinodiscus* and *Biddulphia*.

FIG. 13. Peridinian Plankton consisting mainly of *Ceratium tripos*.

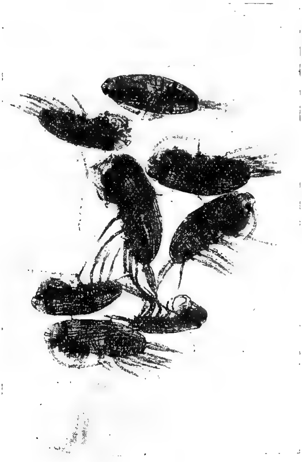


FIG. 14. Copepod Plankton, consisting wholly of *Calanus helgolandicus*.

FIG. 15. Copepod Plankton, consisting mainly of *Acartia discaudata*. One Temora is seen.

two weeks of September, when 22 species were noted. *Chaetoceras* was represented by six species, which made up the bulk of the plankton. *C. decipiens* was the most common Diatom in the autumn maximum, and the specimens were larger and in better condition than usual. A gathering taken in the Bay with the coarse net on 26th September contained over 26½ millions of *Chaetoceras*. Of that number fully 25 millions were *Chaetoceras decipiens*. A noteworthy swarm of *Calanus* occurred on May 17th. A collection measuring 38·5 c.c. contained 48,000 adult *Calanus*. Diatoms were then very scarce. It may be interesting to note that the swarm of *Calanus* was preceded by a well-marked invasion of Dinoflagellates which entered the Bay in May, just after the end of the vernal Diatom maximum. The maximum of this invasion appears to have been reached on the 9th May. On that date the coarse and fine nets captured a total quantity of 23 c.c. of plankton, and the number of Peridinians amounted to 8½ millions.

It is interesting thus to find again, what we have demonstrated before, namely, that Diatoms (see fig. 12), Dinoflagellates (fig. 13), and Copepoda (fig. 15) succeed one another in that order in the summer plankton of the Irish Sea. The unusually large swarm of Peridinians early in May followed close on the termination of the great Diatom maximum in April, and was in its turn succeeded by an unusually large swarm, amounting to about 70,000 in one haul, of large Copepods on May 17th and a few succeeding days. By the 20th of May the large Copepods (*Calanus helgolandicus*, fig. 14) had disappeared, and their place was taken by quantities of the more usual small summer Copepoda (fig. 15). At the very end of May an invasion by the summer Diatom, *Rhizosolenia* (fig. 16) attained unusual dimensions.

Then, again, the autumnal phyto-plankton increase was greater than usual. I happened to be at Port Erin in the latter part of September and took some of the larger Diatom gatherings myself, and I do not think I had ever before seen the water in the Bay swarming so thickly with Diatoms (chiefly species of the genus *Chaetoceras*). The phyto-plankton remained in quantity up till the end of the month, and gradually disappeared during the early days of October.

Fig. 16. Diatom Plankton, consisting mainly of *Rhizosolenia semispina*.

Extended West Coast Investigation.

In our extension of the plankton investigation up the West Coast of Scotland, in addition to visiting many of our former localities in the sea-lochs and around the inner islands, we took observations from the yacht along the chain of the Outer Hebrides, from Barra Head in the Atlantic, at the southern extremity, to Stornoway in the north. Frequent tow-net gatherings were taken, both at the surface and also vertically, with the Nansen net attached to the Lucas sounding machine, many of them from depths of over 100 fathoms, the deepest this year being 145 fathoms off Barra Head. The detailed account of this work is being written up by Mr. Riddell and myself, and will be published later on; but I may remark now that some of the Hebridean hauls this year were so characteristically Oceanic as to contain the pelagic Tunicate *Doliolum tritonis*, the Siphonophore *Cupulita sarsii* and the unusual Copepoda *Euchaeta norvegica*, *Metridia lucens*, *Candacia armata*, and *Centropages typicus*—all of them forms characteristic of Atlantic water.

FIG. 17. Dredging on the "Runa," August, 1912.

In the earlier part of the cruise, when in the neighbourhood of Oban, we had the pleasure of having on board for a couple of days our old friend Mr. Alfred

O. Walker, F.L.S., one of the original members of the L.M.B.C. and a past-President of the Biological Society. Figure 17 shows Mr. Walker on the "Runa" searching the mud brought up from the bottom of the Firth of Lorn for Amphipoda. He has supplied me since with a list of about 30 species of Amphipoda and Isopoda we captured, including *Aristias neglectus*, Hansen, which we had not previously found in these western waters.

Amongst the more interesting captures effected by dredging during this Hebridean cruise was the large compound Ascidian colony called "Syntethys hebridicus" by Professors Edward Forbes and John Goodsir, when they brought it up from 30 fathoms, off the Croulin Islands, near Skye, in 1850, and described it in the Transactions of the Royal Society of Edinburgh the following year (vol. xx, p. 307).

In this paper Forbes and Goodsir tell how they were at the time on a yachting cruise "with our indefatigable friend Mr. McAndrew, among the Hebrides, in the month of August, 1850." This friend was Mr. Robert McAndrew, a Liverpool merchant, who owned the yacht "Naiad," a 70 ton yawl, which he made good use of on dredging expeditions, chiefly in advancing the science of Conchology.

A few sentences quoted from the original description of the "Syntethys hebridicus" dredged from Mr. McAndrew's yacht in 1850 may be of interest in connection with the large specimen obtained by the "Runa" this summer. Forbes and Goodsir go on to say:—

"During this voyage, which lasted three weeks, a series of observations were conducted by means of the dredge and the towing-net . . . . and our exertions were amply rewarded by the discovery of several remarkable

Ascidians and Radiata, some of them so curious in themselves, and so important in their zoological bearings, that we have thought it desirable to lay an account of their characters and anatomy before the Royal Society of Edinburgh. The most remarkable of them is the largest of compound Ascidians yet discovered in the Atlantic. Its nearest described ally is the genus *Diazona* of Savigny, between which animal and *Clavellina* it constitutes a link; one of considerable zoological importance. . . . . The discovery of a creature thus filling up a gap in the animal series was of itself a sufficient harvest from our autumn tour; in this instance our pleasure was enhanced by the beauty and singularity, as well as novelty, of the remarkable animal we have first to describe.

"The SYNTETHYS, for so we propose to designate the Ascidian, presents itself in the form of a compact gelatinous mass of half a foot, and sometimes more in diameter, and very nearly an equal height. It is affixed to the rock or stone by a short, slightly spreading base of various breadth, whence rises as an inverted pyramid the body of the mass, irregularly circular and slightly lobed, spreading out at its summit. It is of a translucent apple-green hue; the surface is nearly smooth. The whole of the expanded disk is thickly studded with individual ascidians growing out, as it were, from the common mass. They are arranged in irregular rows, with a tendency to concentric order. Each individual measures, when full grown, nearly two inches in length, and has the shape of an elongated ampulla, with two terminal orifices, set well apart, but not very prominent, and nearly on the same level. The outer tunic is a smooth and transparent softly cartilaginous sac of a pale emerald green tint, slightly swelling out above the centre, and contracted, but not pedunculated at the base." So far Forbes and Goodsir. We need not follow them into the internal structure; but I have reproduced in fig. 18 the original picture which accompanied the above description; and fig. 19, for comparison, is taken from a water-colour sketch of the largest "Runa" colony when alive, made by my wife.

Our specimens of Syntethys obtained while dredging from the "Runa" this summer were found:—

(1) A few miles south of Barra Head, in the Atlantic, 60 fathoms, one large colony measuring 9½ × 7½ × 5 inches, and of a beautiful translucent pale green colour.

(2) On East Shiant Bank, in the Minch, N. of Skye, 27 fathoms; some smaller pieces.

One of the smaller pieces was preserved in formaline, and it is still of the same pale transparent green hue as when alive. Another fragment was preserved in alcohol, and it became of a pale purple or mauve tint (A on Plate). The large colony was placed in the large tank of methylated spirit and shut up until the end of the cruise. On opening the tank a month later it was found that the spirit was stained green and the colony of Syntethys was now of a well-marked violet colour, recalling vividly the appearance of *Diazona violacea*, from the Mediterranean, described by Savigny in 1816. Fig. 20 is from a photograph of this colony in its present (violet) condition; and B on the Plate shows the colour.

The fact is that, as I pointed out in 1891,* from the examination of a specimen dredged by the late Duke of Argyll off the North Coast of Mull, and which reached my hands through Sir John Murray, it is highly probable that Forbes and

---

* Annals and Mag. of Nat. Hist. for August, 1891.

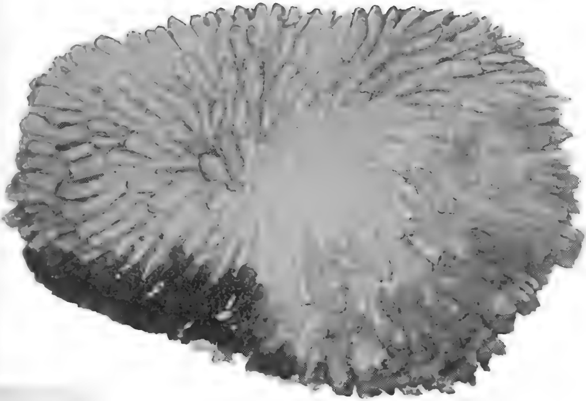


Fig. 19.

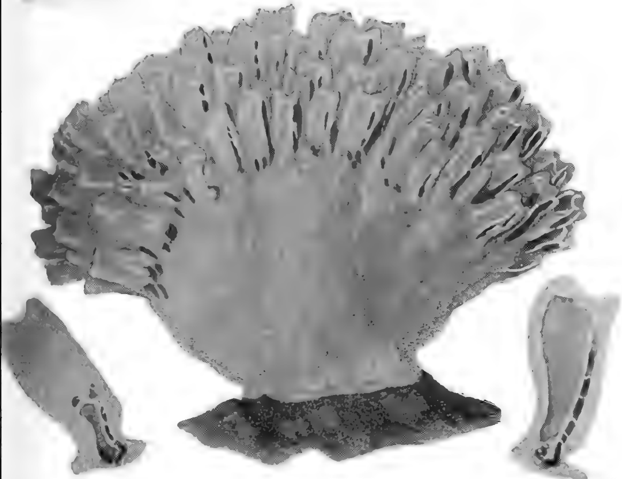


Fig. 18.

Goodsir's "Syntethys" is the same animal as Savigny's "Diazona," but that whereas the animal when living in the Mediterranean is usually violet when alive, the Hebridean form only becomes violet after preservation in alcohol. Professor Reinhard Dohrn, Director of the Zoological Station at Naples, has kindly sent me a pale green Mediterranean specimen, and informs me that both green and violet-coloured specimens have been obtained from time to time in the neighbourhood of Naples. It has not been noticed at Naples that the green colonies change colour in alcohol.

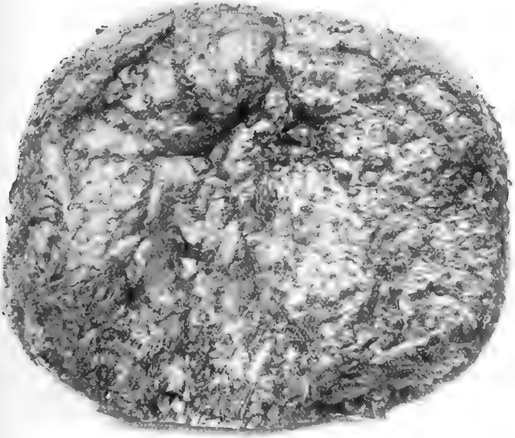


FIG. 20. Violet Hebridean *Diazona* after preservation in alcohol—less than half natural size.

The brilliant green solution which my Hebridean specimen has given with alcohol has been examined spectroscopically for me by Dr. Alfred Holt, Reader in Physical Chemistry in the University, and he has shown me that the pigment is not chlorophyll—as might have been supposed at first—but has a characteristic absorption band in the orange, intermediate in position between the band given by sodium and that of chlorophyll. The position of this band in Ångstrom units is 6200; while chlorophyll gives a band at 6550, and "bonelleine," described by Sorby in 1875 from the green Gephyrean worm *Bonellia viridis*, has the band at 6430. The Syntethys pigment, however, does not go purple with acids and therefore cannot be bonelleine. Acids or alkalies turn it somewhat yellowish, and the colour is not restored on neutralisation. No distinct bands are shown in acid or alkaline solutions. Possibly our substance and bonelleine belong to the same natural group of pigments. Dr. Holt has kindly supplied the diagram (fig. 21) showing the spectrum of the new pigment—to which the name "syntethine" may be applied—compared with those of bonelleine and of chlorophyll.

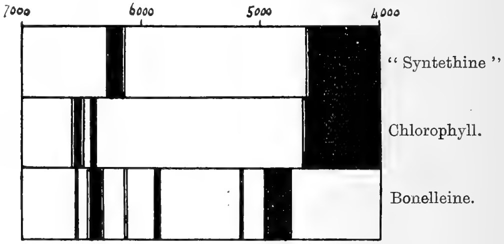


Fig. 21.

It is remarkable to find that the violet-coloured preserved Syntethys still continues to give out the green pigment, as three successive changes of spirit have now, during the last three months, been coloured by it. The violet pigment of the preserved specimen, however, seems to be insoluble, as fragments so coloured have been kept in absolute alcohol, in chloroform, in bisulphide of carbon, and in xylol, for weeks without showing any change in tint.

I am now making a microscopical examination of the tissues of the Hebridean and the Naples specimens in order to determine whether any structural differences can be discovered between these two very similar forms.

L.M.B.C. Memoirs.

Since our last report was published, Memoir XX, on Buccinum, the large whelk, by Dr. W. J. Dakin, has been issued to the public; and Eupagurus, the Hermit Crab, by Mr. H. G. Jackson, M.Sc., is now in the printers' hands and will be issued before the end of the year as Memoir No. XXI. Miss E. L. Gleave, B.Sc., is engaged on a Memoir on Archidoris, the Sea-lemon; and still others are in preparation.

The following shows a list of the Memoirs already published or arranged for:

I. Ascidia, W. A. Herdman, 60 pp., 5 Pls.

II. Cardium, J. Johnstone, 92 pp., 7 Pls.

III. Echinus, H. C. Chadwick, 36 pp., 5 Pls.

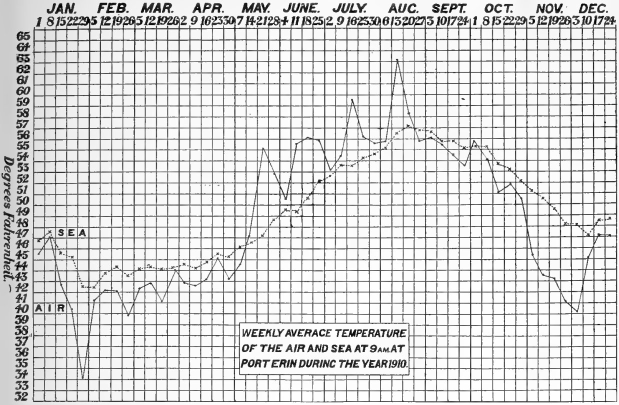
IV. Codium, R. J. H. Gibson and H. Auld, 3 Pls.

V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls.

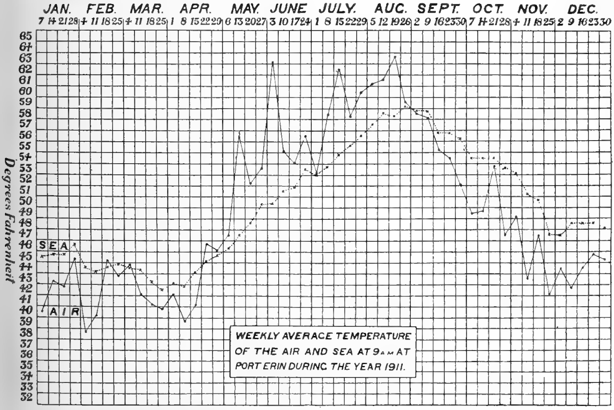
VI. Lepeophtheirus and Lernæa, A. Scott, 5 Pls.

VII. Lineus, R. C. Punnett, 40 pp., 4 Pls.
VIII. Plaice, F. J. Cole and J. Johnstone, 11 Pls.
IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls.
X. Patella, J. R. A. Davis and H. J. Fleure, 4 Pls.
XI. Arenicola, J. H. Ashworth, 126 pp., 8 Pls.
XII. Gammarus, M. Cussans, 55 pp., 4 Pls.
XIII. Anurida, A. D. Imms, 107 pp., 8 Pls.
XIV. Ligia, C. G. Hewitt, 45 pp., 4 Pls.
XV. Antedon, H. C. Chadwick, 55 pp., 7 Pls.
XVI. Cancer, J. Pearson, 217 pp., 13 Pls.
XVII. Pecten, W. J. Dakin, 144 pp., 9 Pls.
XVIII. Eledone, A. Isgrove, 113 pp., 10 Pls.
XIX. Polychaet Larvæ, F. H. Gravely, 87 pp. 4 Pls.
XX. Buccinum, W. J. Dakin, 123 pp., 8 Pls.
XXI. Eupagurus, H. G. Jackson.
Doris, E. L. Gleave.
Actinia, J. A. Clubb.
Cucumaria, E. Hindle.
Halichondria and Sycon, A. Dendy.
Oyster, W. A. Herdman and J. T. Jenkins.
Sabellaria, A. T. Watson.
Ostracod (Cythere), A. Scott.
Asterias, H. C. Chadwick.
Sagitta, E. J. W. Harvey.
Botrylloides, W. A. Herdman.

In addition to these, it is hoped that other Memoirs will be arranged for, on suitable types, such as *Pontobdella*, a Cestode and a Pycnogonid.



WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A.M. AT PORT ERIN DURING THE YEAR 1910.



WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A.M. AT PORT ERIN DURING THE YEAR 1911.

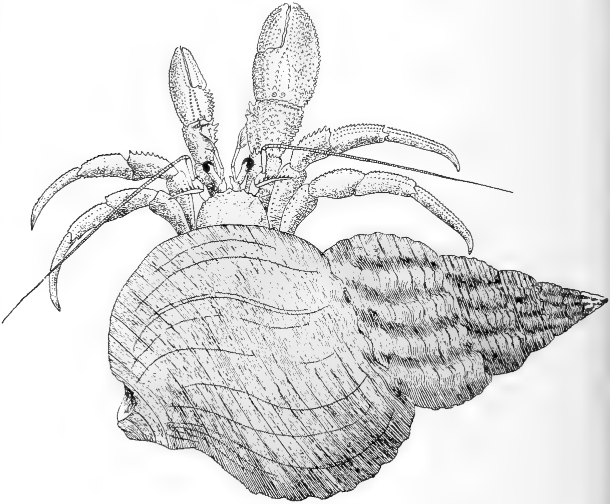
The diagram of sea and air temperatures for 1912, compiled by Mr. Chadwick from his daily records, is not yet completed; but those for the two preceding years, 1910 and 1911, are inserted here to show the general similarity of the two curves along with a few points of divergence, and to demonstrate again the manner in which the temperature of the sea lags behind that of the air in both winter and summer.

We append to this Report:—

(A) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations;

(B) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet.

(C) A collection of the maps and plans of the Port Erin neighbourhood, which it is hoped will be found useful by students working at the Biological Station.



Eupagurus bernhardus, the Hermit Crab, in an empty shell of *Buccinum undatum.*—From a drawing by H. C. Chadwick, A.L.S.

APPENDIX A.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1911).

HIS EXCELLENCY THE RIGHT HON. LORD RAGLAN, Lieut.-Governor of the Isle of Man.

RT. HON. SIR JOHN BRUNNER, BART.

PROF. R. J. HARVEY GIBSON, M.A., F.L.S., Liverpool.

MR. W. J. HALLS, Liverpool.

PROF. W. A. HERDMAN, D.Sc., F.R.S., F.L.S., Liverpool. Chairman of the L.M.B.C., and Hon. Director of the Biological Station.

MR. P. M. C. KERMODE, Ramsey, Isle of Man.

PROF. BENJAMIN MOORE, F.R.S., Liverpool.

SIR CHARLES PETRIE, Liverpool.

MR. E. THOMPSON, Liverpool, Hon. Treasurer.

MR. A. O. WALKER, F.L.S., J.P., formerly of Chester.

MR. ARNOLD T. WATSON, F.L.S., Sheffield.

Curator of the Station—MR. H. C. CHADWICK, A.L.S.
Assistant—Mr. T. N. CREGEEN.

CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The Object of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The Committee shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the Affairs of the Committee shall be conducted by an Hon. Director, who shall be Chairman of the Committee, and an Hon. Treasurer, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any Vacancies on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting, of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The Expenses of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The Biological Station shall be used primarily for the Exploring work of the Committee, and the Specimens collected shall, so far as is necessary, be placed in the first instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

A quiet corner on the North shore of Port Erin bay.

LIVERPOOL MARINE BIOLOGICAL STATION

AT

PORT ERIN.

General Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biological Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are:—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges. Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.

Sea-birds on the Skear at the mouth of Port Erin bay.

MEMORANDA FOR STUDENTS AND OTHERS WORKING AT THE PORT ERIN BIOLOGICAL STATION.

Post-graduate students and others carrying on research will be accommodated in the small work-rooms of the ground floor laboratory and in those on the upper floor of the new research wing. Some of these little rooms have space for two persons who are working together, but researchers who require more space for apparatus or experiments will, so far as the accommodation allows, be given rooms to themselves.

Undergraduate students working as members of a class will occupy the large laboratory on the upper floor or the front museum gallery, and it is very desirable that these students should keep to regular hours of work. As a rule, it is not expected that they should devote the whole of each day to work in the laboratory, but should rather, when tides are suitable, spend a portion at least of either forenoon or afternoon on the sea-shore collecting and observing.

Occasional collecting expeditions are arranged under guidance either on the sea-shore or out at sea, and all undergraduate workers should make a point of taking part in these.

It is desirable that students should also occasionally take plankton gatherings in the bay for examination while living, and boats are provided for this purpose at the expense of the Biological Station to a reasonable extent. Students desiring to obtain a boat for such a purpose must apply to the Curator at the Laboratory for a boat voucher. Boats for pleasure trips are not supplied by the Biological Station, but must be provided by those who desire them at their own expense.

Students requiring any apparatus, glass-ware or chemicals from the store-room must apply to the Curator. Although the Committee keep a few microscopes at the Biological Station, these are mainly required for the use of the staff or for general demonstration purposes. Students are therefore strongly advised, especially during University vacations, not to rely upon being able to obtain a suitable microscope, but ought if possible to bring their own instruments.

Students are advised to provide themselves upon arrival with the "Guide to the Aquarium" (price 3d.), and should each also buy a copy of the set of local maps (price 2d.) upon which to insert their faunistic records and other notes.

Occasional evening meetings in the Biological Station for lecture and demonstration purposes will be arranged from time to time. Apart from these, it is generally not advisable that students should come back to work in the laboratory in the evening; and in all cases all lights will be put out and doors locked at 10 p.m. When the institution is closed, the key can be obtained, by those who have a valid reason for entering the building, only on personal application to Mr. Chadwick, the Curator, at 3, Rowany Terrace.

APPENDIX B.

HON. TREASURER'S STATEMENT.

The Balance Sheet and List of Subscriptions and Donations are shown in the following pages. As the work at Port Erin increases, so do the expenses, and this year they have been rather heavy, and the account shows a balance due to the Hon. Treasurer.

A grant of £25 has been received from the Board of Agriculture for research work, some of which has been spent in Lobster Rearing; particulars of this research are given in the Report.

The Library increases in size slowly, and donations would be very welcome. This year Mrs. Herdman and Prof. R. J. Harvey Gibson have very kindly sent gifts, as shown below.

EDWIN THOMPSON,
Hon. Treasurer.

25, Sefton Drive,
Liverpool.

December 16*th*, 1912.

SUBSCRIBERS.

	£	s.	d.
Briscoe, F. W., Colby, Isle of Man	0	10	6
Browne, Edward T., B.A., Anglefield, Berkhamsted, Herts.	1	1	0
Brunner, Mond & Co., Northwich...	1	1	0
Brunner, Rt. Hon. Sir John, Bart., Silverlands, Chertsey	5	0	0
Brunner, J. F. L., M.P , 23, Weatherley Gardens, London, S.W.	2	2	0
Brunner, Roscoe, Belmont Hall, Northwich ...	1	1	0
Bullen, Rev. R. Ashington, Heathside-road, Woking	1	1	0
Caton, Dr., 78, Rodney-street, Liverpool	1	1	0
Clubb, Dr. J. A., Public Museums, Liverpool ...	0	10	6
Cole, Prof., University College, Reading	1	1	0
Crellin, John C., J.P., Andreas, I. of Man... ...	0	10	0
Dale, Sir Alfred, University, Liverpool	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ...	2	2	0
Graveley, F. H., Indian Museum, Calcutta ...	0	10	6
Halls, W. J., 35, Lord-street, Liverpool	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hewitt, David B., J.P., Northwich	1	1	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Hill, Prof. J. P., University College, London ...	1	1	0
Holland, Walter, Carnatic Hall, Mossley Hill ...	1	1	0
Holt, Dr. Alfred, Dowsefield, Allerton	1	0	0
Holt, Mrs., Sudley, Mossley Hill, Liverpool ...	2	2	0
Holt, P. H., Croxteth-gate, Sefton-park, Liverpool	1	1	0
Huxley, J. S., Prof., Rice Institute, Texas, U.S.A.	1	0	0
Isle of Man Natural History Society	2	2	0
Jarmay, Gustav, Hartford, Cheshire	1	1	0
Livingstone, Charles, 16, Brunswick-st., Liverpool	1	1	0
Manchester Microscopical Society...	1	1	0
Meade-King, R. R., Tower Buildings, Liverpool...	0	10	0
Mond, R., Sevenoaks, Kent...	5	0	0
Forward	£41	17	6

	£	s.	d.
Forward... ...	41	17	6
Monks, F. W., Warrington...	2	2	0
Mosley, F. O., Woodside-road, Beaumont Park, Huddersfield	1	1	0
Mottram, V. H., The University, Liverpool ...	1	1	0
Muspratt, Dr. E. K., Seaforth Hall, Liverpool ...	5	0	0
O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool	1	1	0
Petrie, Sir Charles, Devonshire-road, Liverpool ...	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... ...	1	1	0
Rathbone, Miss May, Northumberland-street, London	1	1	0
Rathbone, Mrs., Green Bank, Allerton, Liverpool	2	0	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	0
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Smith, A. T., 43, Castle-street, Liverpool... ...	1	1	0
Tate, Sir W. H., Woolton, Liverpool	2	2	0
Thompson, Edwin, 25, Sefton Drive, Liverpool ...	1	1	0
Thornely, Miss, Nunclose, Grassendale	0	10	0
Thornely, Miss L. R., Nunclose, Grassendale ...	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool ...	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Watson, A. T., Tapton-crescent Road, Sheffield ...	1	1	0
Whitley, Edward, Oxford	2	2	0
Weiss, Prof. F. E., University, Manchester ...	1	1	0
Wiglesworth, Dr., Rainhill...	1	1	0
Wragg, Sir W., D.C.L., Port St. Mary, Isle of Man	1	1	0
Yates, Harry, 75, Shudehill, Manchester	1	1	0
	£77	13	6
Add old Subscriptions received *less* Subscriptions still unpaid	8	13	6
	£86	7	0

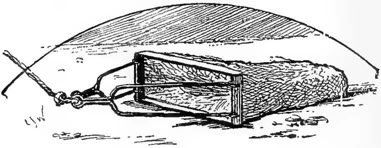
SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

	£	s.	d.
Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
University College, London	2	2	0
Bedford College for Women, London	2	2	0
University College, Reading	2	2	0
	£36	6	0
Deduct Subscriptions still unpaid	10	0	0
	£26	6	0

DONATIONS TO LIBRARY.

Prof. R. J. Harvey Gibson—The current numbers of "Nature."

Mrs. Herdman—The British Association Reports for the last 20 years.



The Naturalist's Dredge.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr. IN ACCOUNT WITH EDWIN THOMPSON, HON. TREASURER. **Cr.**

1912.	£	s.	d.
To Printing and Stationery	25	1	7
,, Boat Hire	8	18	0
,, Books and Apparatus at Port Erin Biological Station	34	3	2
,, Postage, Carriage, &c.	6	11	6
,, Expenses for Collecting Specimens	10	0	0
,, Salary—Share of Curator's	75	0	0
,, ,, ,, Assistant's	27	16	6
,, Sundries	5	5	6
,, Guides to Aquarium	40	8	0
,, Experiments in Lobster rearing	13	6	0
	£246	10	3

1912.	£	s.	d.
By Balance in hand December, 1911	0	14	9
,, Subscriptions and Donations received	86	7	0
,, Amount received from Universities for hire of "Work Tables"	26	6	0
,, Laboratory Fees—Prof. B. Moore	10	10	0
,, Admissions to Aquarium, Share of	24	13	8
,, Interest on British Association (1896) Fund	37	13	4
,, Sale of Guides	9	15	6
,, Sale of Memoirs	4	10	0
,, ,, Post Cards	0	11	7
,, Sale of Specimens, Bottles, &c,	4	0	9
,, Bank Interest	4	3	2
,, Board of Agriculture Grant	25	0	0
,, Balance due Hon. Treasurer	12	4	6
	£246	10	3

Endowed Invested Fund:—	£	s.	d.
British Workman's Public House Co. 99 Shares £1 each fully paid.			
Memoir Fund—Balance in Bank, December, 1911	179	6	0
Expenses of Buccinum Memoir	46	12	10
	£132	13	2

Extension Fund:—	£	s.	d.
Balance, December, 1911	41	4	3
Deduct Payments during year 1912	3	19	6
	£37	4	9

EDWIN THOMPSON,
HON. TREASURER.

LIVERPOOL, *December 16th, 1912.*

Audited and found correct,
COOK & LEATHER,
Chartered Accountants.

Liverpool Marine Biology Committee

BOOK OF MAPS

FOR THE USE OF

STUDENTS

AT

PORT ERIN

PRICE TWO PENCE

1913

G

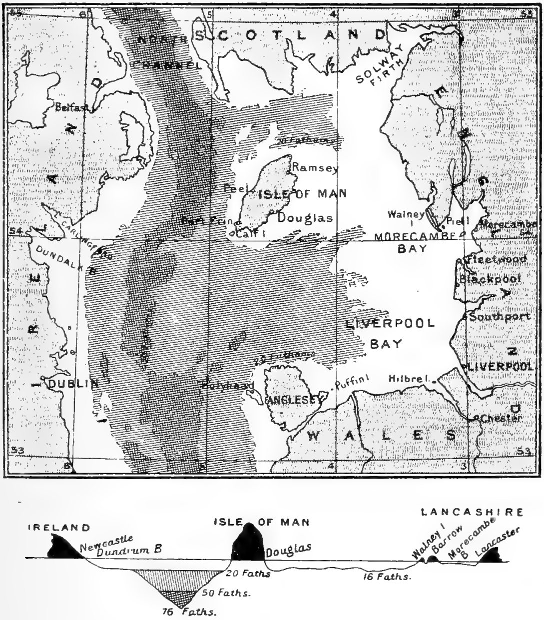
NOTE.

It frequently happens that some of the advanced students or researchers who come to Port Erin for faunistic work require to have the set of the tides, the lie of the land, and the position of the characteristic habitats and best collecting grounds explained with the help of plans and sketches. It is also the case that some students find it necessary to make for themselves little maps on which to record localities and captures. It is hoped, therefore, that the issue of the following sketch-maps, charts and plans of Port Erin Bay and the neighbourhood, which have been prepared from time to time for the Annual Reports, in this form—with space for notes—may be found useful to many of our workers at the Biological Station.

W. A. HERDMAN.

December, 1912.

NOTES.

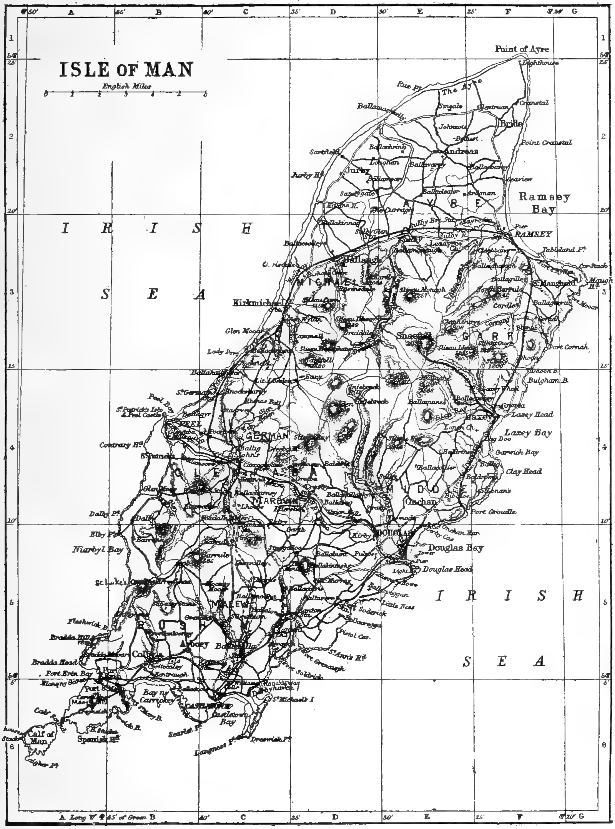


Sketch Map and Section of the Irish Sea Basin, showing the contrast in depth of water to the East and to the West of the Isle of Man.

NOTES.

Course of Flood tide in Irish Sea round Isle of Man.
SCALE: 20 sea miles = 1½ inches.

NOTES.



Topography of Isle of Man and Calf Island.

NOTES.

The Sea and Coast-line round the South End of the Isle of Man.

NOTES.

[Explanation of the numbers on the chart opposite will be found in the 14th Annual Report of the L.M.B.C. (1900), at page 36.]

Chart of the South-Western Corner of the Isle of Man, from Fleshwick to Perwick, showing the distribution of its Marine Fauna.

NOTES.

[The first of the following six charts of the more restricted area of Port Erin Bay (on a larger scale, about seven inches to the mile), shows the physical features, the soundings, and the nature of the bottom. In this, as well as in the other five, are inserted the principal contours of depth, and also a series of magnetic north and south and east and west lines dividing the area into twenty squares, each measuring about 700 feet to the side. The positions of the lines are determined by prominent objects on the shore, which will be easily recognised, and as the vertical and horizontal columns are lettered and numbered, anyone with a little practice, when boating in the bay, will be able to determine in most cases what square he is in. The squares should be quoted by letter and numeral, and will soon become familiar to workers at the Station. For example, the Biological Station itself lies opposite square C.3, the Traie Maenagh swimming bath is in A.1, the small boat jetty in B.3, and the buoy at the entrance to the bay is at the junction of four squares.

The remaining five charts deal each with one or more of the chief groups of animals.]

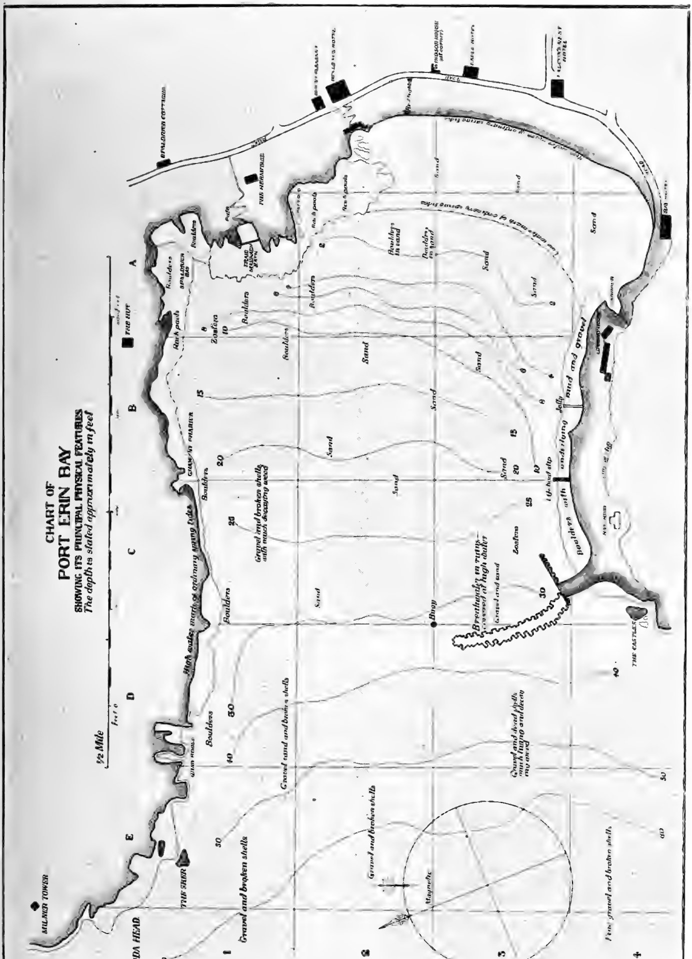


CHART OF
PORT ERIN BAY
SHOWING ITS PRINCIPAL PHYSICAL FEATURES
The depth is stated approximately in feet

NOTES.

[Explanation of the numbers on the chart opposite will be found in the 14th Annual Report of the L.M.B.C. (1900), at page 47.]

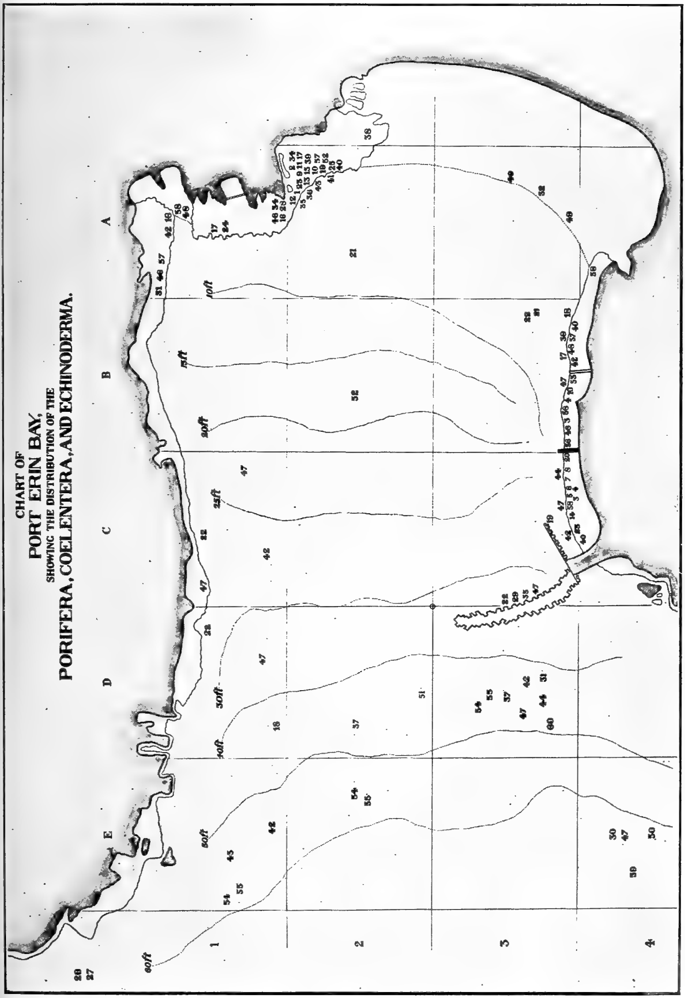


CHART OF
PORT ERIN BAY,
SHOWING THE DISTRIBUTION OF THE
PORIFERA, COELENTERA, AND ECHINODERMA.

NOTES.

[Explanation of the numbers on the chart opposite will be found in the 14th Annual Report of the L.M.B.C. (1900), at page 50.]

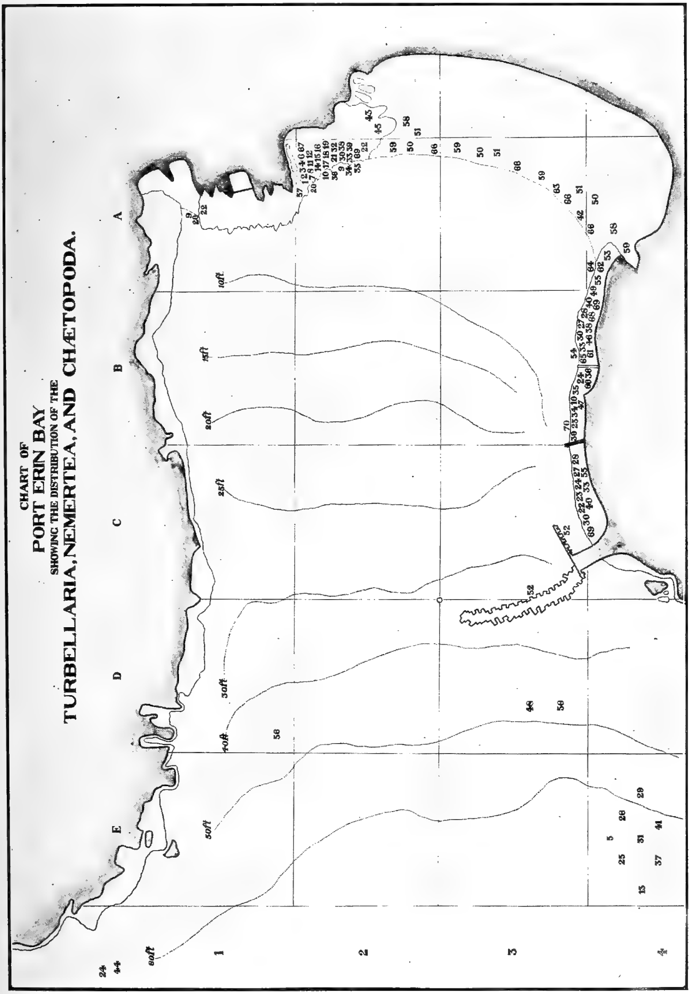


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
TURBELLARIA, NEMERTEA, AND CHÆTOPODA.
A
B
C
D
E
1
2
3
4
10ft
15ft
20ft
25ft
30ft
40ft
50ft
60ft

NOTES.

[Explanation of the numbers on the chart opposite will be found in the 14th Annual Report of the L.M.B.C. (1900) at page 52.]

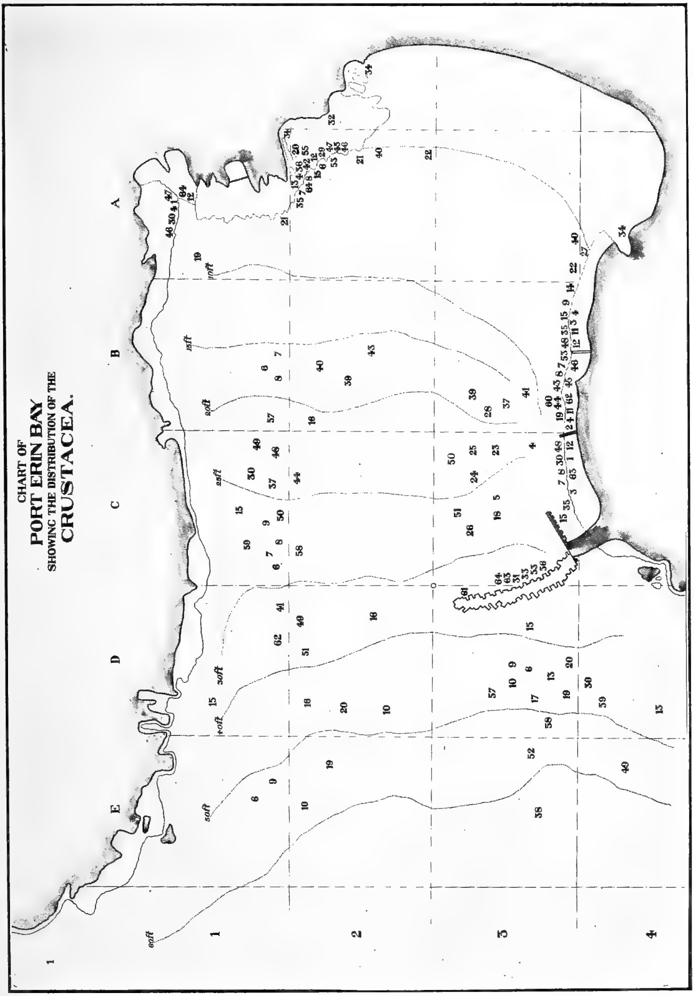


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
CRUSTACEA.
A
B
C
D
E
1
2
3
4
10ft
15ft
20ft
25ft
30ft
40ft
50ft
60ft

NOTES.

[Explanation of the numbers on the chart opposite will be found in the 14th Annual Report of the L.M.B.C. (1900), at page 54.]

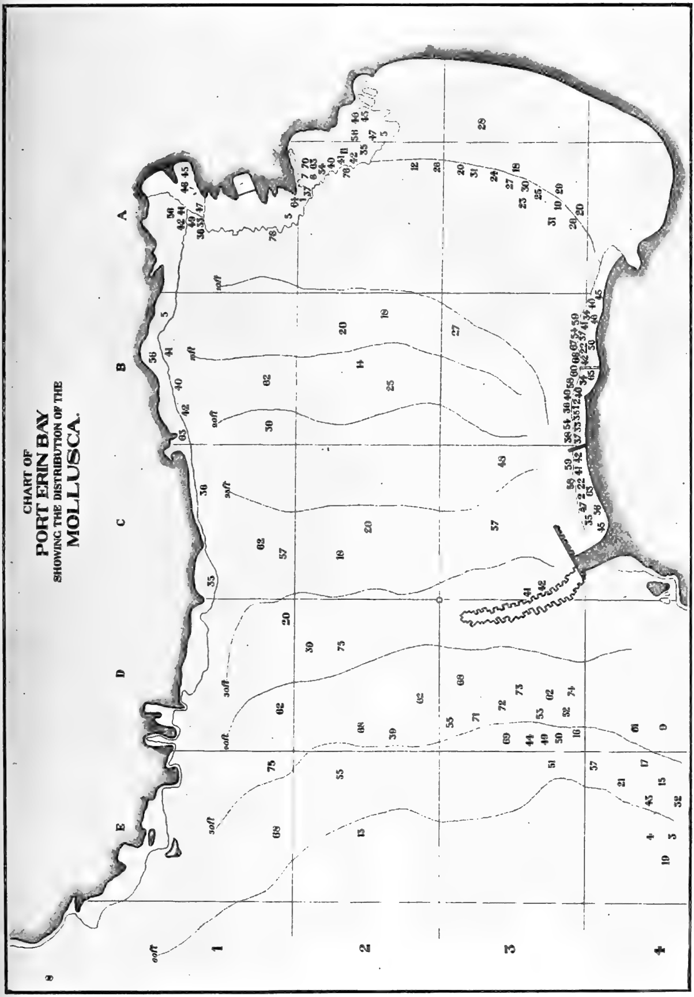


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
MOLLUSCA.
A
B
C
D
E
1
2
3
4
soft

NOTES.

[Explanation of the numbers on the chart opposite will be found in the 14th Annual Report of the L.M.B.C. (1900), at page 57.]

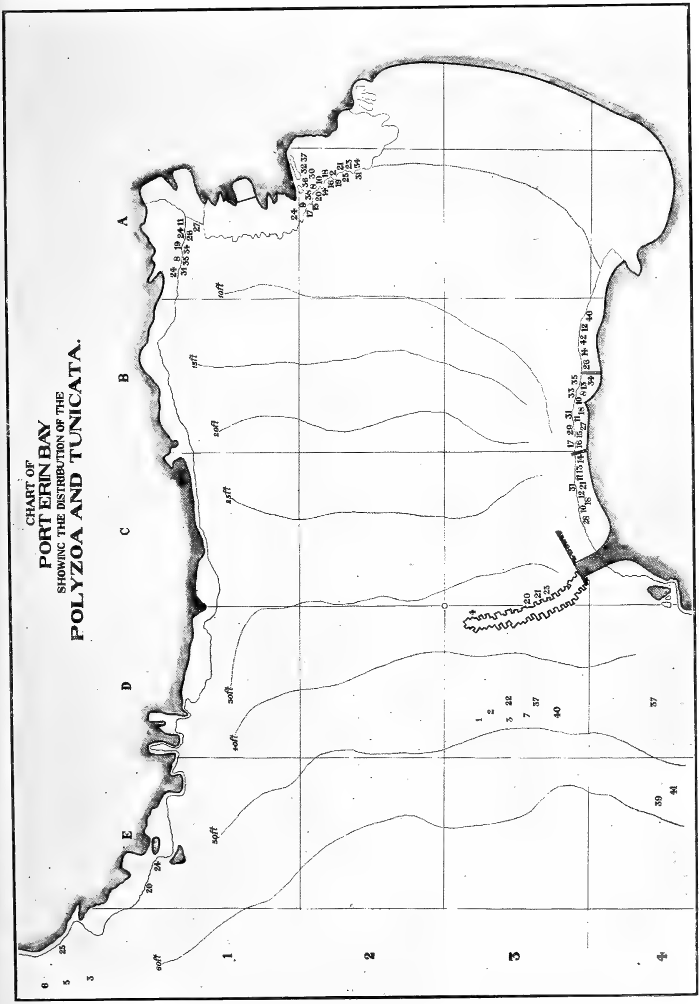


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
POLYZOA AND TUNICATA.
A
B
C
D
E
1
2
3
4
10ft
15ft
20ft
25ft
30ft
40ft
50ft
60ft

OBSERVATIONS ON THE MARINE ALGAE OF THE L.M.B.C. DISTRICT (Isle of Man Area).

By R. J. Harvey-Gibson, M.A., F.L.S., Professor of Botany; Margery Knight, B.Sc., Assistant Lecturer in Botany; and Hilda Coburn, B.Sc., Hartley Botanical Laboratories, University of Liverpool.

In 1890 a paper was published by one of us (R. J. H.-G.) on the Marine Algae of the Liverpool Marine Biological Committee's District,[1] which was itself a revision and extension of a previous paper published in 1889.[2] The period of twenty-three years which has elapsed since the compilation of the former of these lists has not, so far as we know, been productive of any algological research in the district, and consequently we have thought it worth while to place on record some observations made by us during two Easter Vacation periods (1911 and 1912), more with the view of showing how much yet remains to be done than of attempting to compile a complete catalogue of the Marine Algae even of the limited area to which our attention has been more especially directed during the period in question, viz., the south end of the Isle of Man.

We have, for convenience of reference, continued to use the classification and nomenclature followed in the last Report,[1] although the taxonomy of Marine Algae has undergone considerable modification since the date of Holmes and Batters' "Revised List of the British Marine Algae,"[3] the classificatory system in which was followed on that occasion. We have, however, adopted such changes in generic and specific nomenclature as were put forward by Mr. Batters in his "Revised Catalogue" published in 1902.[4] In the 1890 list a census table was given of species found in the four localities there defined as (*a*) the Mersey and Dee estuaries; (*b*) Hilbre Island; (*c*) Anglesea and Puffin Island; (*d*) Isle of Man. The table is repeated here in a corrected form, some names having been slipped apparently in the counting:—

	(*a*)	(*b*)	(*c*)	(*d*)	
Cyanophyceae	14	7	13	1	—
Chlorophyceae	21	16	31	23	(40)
Phaeophyceae	12	38	55	47	(69)
Rhodophyceae	24	57	93	109	(139)
	71	118	192	180	(248)

The numbers in brackets following the last column indicate the census in the present list, from which it will be seen that 68 species have been added to the catalogue of the Marine Algae of the Isle of Man.

From this table it will be seen that although, so far as known in 1890, the marine flora of the Isle of Man is a fairly rich one, it includes twelve species fewer than the Puffin Island list, although that island is not more than a couple of miles in circumference. This must not be taken to indicate that the Mona of Tacitus is exceptionally rich as regards Marine Algae when compared with the vastly larger Mona of Cæsar, but merely that Marine Algae had been assiduously collected in the one district and not in the other. With the exception of the "Revised List" drawn up by one of us in 1890, the only papers known to us dealing with the Marine Algae of the Isle of Man are one by Dr. Brady, published in 1861,[5] one by the Rev. T. Talbot on the Flora of Douglas Bay, published in 1890,[6] and one by Mr. King published in 1889.[7] The identifications recorded in these papers were incorporated in the Revised Report. Short lists are also furnished by Mrs. Gatty[8] and Mr. Garner.[9]

The present paper deals with observations made by us at Port Erin, Port St. Mary, Fleshwick Bay, in April, 1911, and April, 1912, and by two of us (M. K. and H. C.) at Peel in July and August, 1911, and August, 1912.

We have omitted from our present list all reference to the so-called Cyanophyceae, partly on account of the difficulties of identification which such forms present, but chiefly because it is now becoming customary to exclude this group entirely from Algae, in the strict sense of the term, and to associate them with the Bacteria as Schizophyta. The Diatomaceae will also receive special treatment at the hands of Miss E. M. Blackwell, M.Sc.

Species which have been collected by one or other of us are indicated by the locality only; other species recorded, but not seen by us, have appended to them, in addition to the locality, also the collector's name, when known. Species which, so far as we are aware, have not been previously recorded from the Isle of Man, are distinguished by an asterisk.

CHLOROPHYCEAE.

Cohort II. CONFERVINAE.

Ord. I. Blastosporaceae.

**Prasiola stipitata*, Suhr. Peel.

Ord. II. Ulvaceae.

Monostroma grevillei, Wittrock. Port S. Mary, Port Erin, Douglas Bay (Talbot).

Enteromorpha clathrata, J. Ag. Port Erin, Peel.

E. compressa, Grev. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

E. linza, J. Ag., f. *lanceolata*, Kütz. Port Erin, Port S. Mary, Douglas Bay (Talbot).

**E. intestinalis*, Link. Port Erin, Port S. Mary.

**E. ramulosa*, Hook. Port Erin, Port S. Mary.

**E. ralfsii*, Harv. Port Erin.

**E. paradoxa*, Kütz. Port Erin.

**Percursaria percursa*, Ros. Peel. (With parasitic *Blastophysa arrhiza*, Wille.)

Ulva lactuca, L. var. *latissima*, D.C. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

Ord. IV. CHAETOPHORACEAE.

**Endoderma wittrockii*, Wille. Port Erin.

**E. flustrae*, Batt. Port Erin.

Ord. V. CLADOPHORACEAE.

**Urospora isogona*, Batt. Port Erin.

**U. bangioides*, Holmes & Batt. Port Erin (zoogonidia and gametes).

U. flacca, Holmes & Batt. Port S. Mary.

Chaetomorpha tortuosa, Kütz. Port S. Mary, Douglas Bay (Mrs. Gatty).

Ch. melagonium, Kütz. Port Erin, Port S. Mary, Clay Head (Brady), Douglas Bay (Talbot).

**Ch. linum*, Kütz. Port Erin, Port S. Mary.

Ch. aerea, Kütz. Port Erin, Douglas Bay (Talbot), Peel.

Ch. litorea, Cook. Douglas Bay (Talbot).

**Rhizoclonium riparium*, Harv. Port Erin.

Cladophora hutchinsiae, Harv. Port S. Mary, Douglas Bay (Talbot).

Cl. utriculosa, Kütz. var. *laetevirens*, Hauck. Port Erin, Douglas Bay (Talbot), Port S. Mary.

Cl. rupestris, Kütz. Port Erin, Port S. Mary, Douglas Bay (Talbot)

Cl. rupestris, var. *nuda*, Holm. & Batt. Port Erin, Port S. Mary.

Cl. flexuosa, Harv. Port Erin.

Cl. albida, Kütz. Douglas Bay (Mrs. Gatty).

Cl. albida, var. *refracta*, Thur. Port Erin, Douglas Bay (Brady).

Cl. arcta, Kütz. Port Erin, Douglas Bay (Talbot).

Cl. lanosa, Kütz. Port Erin, Douglas Bay (Talbot).

Cl. lanosa, var. *uncialis*, Thur. Douglas Bay (Talbot).

Cl. pellucida, Kütz. Port Erin, Port S. Mary. (With *Schmitziella endophloea*, Born. & Batt.)

**Cl. fracta*, Kütz. Port Erin.

Cl. gracilis, Kütz. Port Erin, Douglas Bay (Talbot).

Cohort III. SIPHONINAE.

Ord. I. Bryopsidaceae.

**Blastophysa arrhiza*, Wille. (Protosiphonaceae) Peel.

Bryopsis hypnoides, Lamx. Port Erin, Douglas Bay (Talbot).

B. plumosa, C. Ag. Port Erin, Port S. Mary, Peel, Douglas Bay (Brady, Garner).

Ord. IV. Codiaceae.

Codium tomentosum, Stackh. (With gametangia.) Port Erin, Port S. Mary, Peel.

**C. mucronatum*, Cott. Port Erin, Port S. Mary.

PHAEOPHYCEAE.

Cohort I. ECTOCARPINAE.

Ord. I. Desmarestiaceae.

Desmarestia viridis, Lamx. Port Erin, Port S. Mary, dredged off Contrary Head, Douglas Bay (Talbot).

D. aculeata, Lamx. Port Erin, dredged off Contrary Head, Douglas Bay (Talbot), Port S. Mary, Peel.

D. ligulata, Lamx. Port Erin, Peel.

Ord. II. DICTYOSIPHONACEAE.

Dictyosiphon foeniculaceus, Grev. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Ord. III. PUNCTARIACEAE.

Litosiphon pusillus, Harv. Port Erin, Douglas Bay (Talbot).

**L. laminariae*, Harv. Port Erin.

**Stictyosiphon griffithsianus*, Holm. & Batt. Port Erin.

**Striaria attenuata*, Grev. Port Erin (with gonidangia).

Punctaria latifolia, Grev. Douglas Bay (Talbot).

P. tenuissima, Grev. Port Erin, Douglas Bay (Brady).

Ord. IV. ASPEROCOCCACEAE.

Myriotrichia clavaeformis, Harv. Peel, Port Erin, Douglas Bay (Talbot).

M. filiformis, Harv. Port Erin, Peel, Douglas Bay (Brady).

Asperococcus echinatus, Grev. Port Erin, dredged off Contrary Head, Douglas Bay (Talbot).

Ord. V. ECTOCARPACEAE.

Ectocarpus terminalis, Kütz. Port Erin.

E. siliculosus, Kütz. Port Erin, Douglas Bay (Talbot), Port S. Mary.

E. tomentosus, Lyngb. Port Erin, Port S. Mary, Douglas Bay (Talbot).

**E. crinitus*, Carm. Port Erin, Port S. Mary.

**E. fasciculatus*, Harv. Port Erin.

**E. granulosus*, C. Ag. Port Erin.

**E. hincksiae*, Harv. Port Erin.

**Isthmoplea sphaerophora*, Kjell. Port Erin, Port S. Mary.

Pylaiella litoralis, Kjellm. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Isthmoplea sphaerophora, first observed by Carmichael about 1824, is described by Harvey (Phyc. Brit. pl. CXXVI) under the name of *Ectocarpus sphaerophorus,* but was placed in the genus *Isthmoplea* by Kjellman (Algenv. Murm. Meer) more especially on account of the mode of origin of the asexual reproductive organs.

The gonidangia arise singly or in pairs as lateral segments, formed by longitudinal division of an ordinary vegetative cell. Gametangia have not, so far as we are aware, been found.

At Port Erin, as elsewhere, *I. sphaerophora* grows as an epiphyte on *Plumaria elegans.* Amongst material collected in April, 1911, we found, on subsequent microscopic examination, many plants some of which bore gonidangia and others gametangia. These latter were growing side by side on the same host, the sexual plants being inextricably intertwined with the asexual forms. Both forms corresponded in every detail, as may be seen by comparing the vegetative cells figured on Plate, figs. 4, 5. The gametangia are of the normal Ectocarpus type, and are developed at the ends of short lateral branches composed of two or three cells. Each gametangium is on an average 0·07 mm. long, and tapers from base to apex. It would appear, therefore, that the only distinctive feature of *Isthmoplea,* as a genus, is the somewhat peculiar mode of origin of the gonidangia and their semi-imbedded nature when mature.

Hauck (Meeresalgen, p. 331) records his having occasionally found gonidangia and gametangia on the same plant of *Ectocarpus confervoides.* On an undetermined species of *Ectocarpus* we also found gametangia and gonidangia on the same branch not infrequently formed from contiguous cells (Plate, fig. 7).

In a paper on the life-history of *Polysiphonia violacea,* Yamanouchi (Bot. Gaz. Vol. XLII) demonstrates a regular alternation of generations in that species between a gametophyte, the nuclei of whose cells have 20 chromosomes, and a sporophyte whose nuclei have 40 chromosomes. At the same time he records under the head of "Abnormalities" the occurrence of tetragonidia on cystocarpic or antheridial plants, and refers to similar cases noted by Lotsy in *Chylocladia kaliformis,* and by Davis in *Spermothamnion turneri* and *Callithamnion baileyi.* He adds "such cases should be carefully investigated to determine whether true tetraspores are present or whether the structures are not really of the nature of monospores, as in *Polysiphonia,* and developed with a suppression of reduction phenomena." In the plants of *Polysiphonia violacea* collected by us at Port Erin in 1912, cystocarpia and gonidangia were frequently present on the same branch, and the number of cases we met with, both in that species and in other genera, in our opinion scarcely justifies the view that all of these are to be regarded as "abnormalities." We have also found sexual and asexual organs on the same branch in *Lophothalia byssoides, Callithamnion hookeri, C. tetragonum, C. corymbosum* and in *Hypnaea valentiae,* a species obtained from the Soudan litoral. Mr. A. D. Cotton informs us that he has noted the same joint occurrence of sexual and asexual organs on the same plant in *Laurencia hybrida* and in an undetermined species of *Callithamnion.* Indeed, we have been forced to the opinion that the constant alternation of sexual and asexual stages, as emphasised by Yamanouchi, is open to criticism, and that the occurrence of tetragonidia, cystocarpia and antheridia on the same plant is by no means an exceptional phenomenon.

Ord. VII. ELACHISTACEAE.

**Myriactis stellulata*, Batt. (With gonidangia.) Peel, Port Erin.

Elachista scutulata, Duby. Port S. Mary, Douglas Bay (Talbot).

E. fucicola, Fries. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Ord. VIII. SPHACELARIACEAE.

Sphacelaria radicans, Harv. Port Erin, Port S. Mary.

S. cirrhosa, C. Ag. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

S. cirrhosa, var. *fusca*, Holm. & Batt. Douglas Bay (Brady).

Chaetopteris plumosa, Kütz. Port Erin, Douglas Bay (Talbot), Peel.

Halopteris filicina, Kütz. Port Erin.

Cladostephus spongiosus, C. Ag. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

Cl. verticillatus, C. Ag. Port Erin, Douglas Bay (Talbot), Peel.

Stypocaulon scoparium, Kütz. Port Erin, Douglas Bay (Talbot).

Ord. IX. MYRIONEMACEAE.

Myrionema strangulans, Grev. Port Erin, Douglas Bay (Brady, Talbot).

Ascocyclus orbicularis, Magn. Douglas Bay (Talbot).

A. leclancherii, Magn. Peel, Douglas Bay (Brady).

**Ralfsia verrucosa*, Aresch. Port Erin.

Ord. X. CHORDARIACEAE.

Chordaria flagelliformis, C. Ag. Douglas Bay (Talbot), Port Erin.

Mesogloea vermiculata, Le Jol. Port Erin, Douglas Bay (Brady, Talbot).

Castagnea virescens, Thur. Douglas Bay (Brady, Talbot).

Leathesia difformis, Aresch. Port Erin, Port S. Mary, Peel, Douglas Bay (Talbot).

Cohort II. LAMINARINAE.

Ord. I. Scytosiphonaceae.

Phyllitis zosterifolia, Rke. Port Erin, Port S. Mary.

Ph. fascia, Kütz. Port Erin, Douglas Bay (Talbot).

Scytosiphon lomentarius, J. Ag. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Ord. II. Chordaceae.

Chorda filum, Stackh. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

**Ch. tomentosa*, Lyngb. Port Erin.

Ord. III. Laminariaceae.

Laminaria saccharina, Lamx. Port Erin, Port S. Mary, Douglas Bay (Talbot).

L. saccharina, f. *phyllitis*, Le Jol. Port S. Mary.

L. cloustoni, Edm. Port Erin, Port S. Mary.

L. digitata, Lamx. Douglas Bay (Talbot), Port Erin, Peel.

Saccorhiza bulbosa, De la Pyl. Port Erin, Fleshwick, Port S. Mary, Douglas Bay (Mrs. Gatty), Peel.

Alaria esculenta, Grev. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Cohort III. SPOROCHNINAE.

Ord. I. Sporochnaceae.

Sporochnus pedunculatus, C. Ag. (With gonidangia.) Peel, Douglas Bay (Mrs. Gatty).

**Stilophora rhizodes*, (Ehrb.) J. Ag. Port Erin.

Cohort IV. CUTLERINAE.

Ord. I. CUTLERIACEAE.

Cutleria multifida, Grev. Douglas Bay (Talbot).

Cohort V. FUCINAE.

Ord. I. FUCACEAE.

Fucus vesiculosus, L. Port Erin, Port S. Mary, Fleshwick, Douglas Bay (Talbot), Peel.

F. serratus, L. Port Erin, Port S. Mary, Fleshwick, Douglas Bay (Talbot).

**F. spiralis*, L. var. *platycarpus*, Thur. Port Erin.

**F. ceranoides*, L. Port Erin, Port S. Mary.

Ascophyllum nodosum, Le Jol. Port Erin, Port S. Mary, Peel, Douglas Bay (Talbot).

Pelvetia canaliculata, Dcne. & Thur. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

Himanthalia lorea, Lyngb. Port Erin, Port S. Mary, Port Soderick (Talbot), Calf (Garner), Fleshwick.

Halidrys siliquosa, Lyngb. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Cystoseira ericoides, C. Ag. Douglas Bay (Garner).

C. discors, C. Ag. Douglas Bay (Garner).

C. fibrosa, C. Ag. Douglas Bay (Garner).

Cohort VII. DICTYOTINAE.

Ord. I. DICTYOTACEAE.

Dictyota dichotoma, Lamx. (With gonidangia and gametangia.) Peel, Port Erin, Douglas Bay (Brady, Talbot).

**D. ligulata*, Kütz. Port Erin, Port S. Mary.

Dictyopteris membranacea, Batt. Douglas Bay (Talbot).

RHODOPHYCEAE.

Cohort I. PORPHYRINAE.

Ord. I. Porphyraceae.

Porphyra umbilicalis, Kütz. var. *laciniata*, J. Ag. Port Erin, Douglas Bay (Talbot).

**P. leucosticta*, Thur. Port Erin.

**P. ciliaris*, Crn. Peel.

**Bangia fuscopurpurea*, Lyngb. Port S. Mary.

**Erythrotrichia carnea*, J. Ag. Port S. Mary.

Cohort II. NEMALIONINAE.

Ord. I. Helminthocladiaceae.

Acrochaetium virgatulum, J. Ag. Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot).

A. daviesii, Näg. Port S. Mary, Douglas Bay (Mrs. Gatty).

**Nemalion multifidum*, J. Ag. (With cystocarpia.) Peel.

Helminthocladia purpurea, J. Ag. Port Erin, Peel, Douglas Bay (Talbot).

Ord. III. Gelidiaceae.

Naccaria wigghii, Endl. Douglas Bay (Mrs. Gatty).

Gelidium corneum, Lamx. Port Erin, Port S. Mary, Fleshwick, Douglas Bay (Talbot).

G. crinale, J. Ag. Peel, Port Erin, Port S. Mary, Douglas Bay (Talbot).

Cohort III. GIGARTININAE.

Ord. I. Gigartinaceae.

Chondrus crispus, Stackh. Port Erin, Port S. Mary, Fleshwick, Douglas Bay (Talbot), Peel.

Gigartina stellata, Batt. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

Phyllophora rubens, Grev. Port Erin, Fleshwick, Kirk Onchan (Brady), Douglas Bay (Talbot).

Ph. membranifolia, J. Ag. Port Erin.

Ph. palmettoides, J. Ag. Douglas Bay (Talbot).

**Ph. brodiaei*, J. Ag. Port Erin.

Gymnogongrus griffithsiae, Mart. Port Erin, Laxey (Mrs. Gatty), Douglas Bay (Talbot).

G. norvegicus, J. Ag. Douglas Bay (Talbot).

Ahnfeldtia plicata, Fries. Port Erin, Port S. Mary, Douglas Bay (Talbot).

**Actinococcus roseus*, Kütz. Port Erin, Port S. Mary.

**Callophyllis laciniata*, Kütz. (With cystocarpia.) Port Erin, Douglas Bay (Talbot), Peel.

**Callymenia reniformis*, J. Ag. Port Erin.

Ord. II. RHODOPHYLLIDACEAE.

Cystoclonium purpureum, Batt. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

Catenella opuntia, Grev. Port Erin, Fleshwick, Douglas Bay (Brady, Talbot).

Euthora cristata, J. Ag. (With cystocarpia.) Douglas Bay (Talbot), Peel.

Rhodophyllis bifida, Kütz. Port Erin, Port S. Mary, Douglas Bay (Mrs. Gatty).

Cohort IV. RHODYMENINAE.

Ord. I. SPHAEROCOCCACEAE.

Sphaerococcus coronopifolius, Grev. (With cystocarpia). Port Erin, Douglas Bay (Mrs. Gatty), Peel.

Gracilaria confervoides, Grev. Douglas Bay (Talbot).

Calliblepharis ciliata, Kütz. Douglas Bay (Mrs. Gatty), Peel.

C. jubata, Kütz. Douglas Bay (Talbot), Port Erin.

Ord. II. RHODYMENIACEAE.

Rhodymenia palmata, Grev. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

**Rh. palmetta*, Grev. Port Erin.

Lomentaria articulata, Lyngb. Port Erin, Port S. Mary, Douglas Bay (Talbot).

L. clavellosa, Gaill. Port Erin, Port S. Mary, Douglas Bay (Talbot).

**L. rosea*, Thur. Port Erin.

Champia parvula, Harv. Port Erin, Douglas Bay (Talbot).

Chylocladia kaliformis, Grev. Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot), Peel.

C. ovalis, Hook. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Plocamium coccineum, Lyngb. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Ord. III. DELESSERIACEAE.

Nitophyllum laceratum, Grev. Port Erin, Port S. Mary, Douglas Bay (Talbot).

N. punctatum, Grev. Douglas Bay (Talbot), Port Erin.

**N. gmelini*, Harv. Port Erin, Peel.

Delesseria alata, Lamx. Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot).

**Delesseria alata*, var. *angustissima*, Hauck. Port Erin.

D. sinuosa, Lamx. Port Erin, Port S. Mary dredged off Contrary Head, Douglas Bay (Brady, Talbot).

D. hypoglossum, Lamx. Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot), Fleshwick.

D. ruscifolia, Lamx. Port S. Mary, dredged off Contrary Head, Douglas Bay (Brady, Talbot),

D. sanguinea, Lamx. Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot).

Ord. IV. BONNEMAISONIACEAE.

Bonnemaisonia asparagoides, C. Ag. Douglas Bay (Brady, Talbot).

Ord. V. RHODOMELACEAE.

Rhodomela subfusca, C. Ag. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

Rh. lycopodioides, C. Ag. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

Odonthalia dentata, Lyngb. (With gonidangia.) Port Erin, Port S. Mary, Fleshwick, Douglas Bay (Talbot).

Laurencia obtusa, Lamx. (With antheridia.) Port Erin, Port S. Mary, Douglas Bay (Talbot).

L. pinnatifida, Lamx. Port Erin, Port S. Mary, Douglas Bay (Talbot).

**L. hybrida*, Lenorm. Port Erin.

Chondria tenuissima, C. Ag. Douglas Bay (Talbot).

**C. dasyphylla*, (Woodw.) Ag. Peel.

Polysiphonia fibrata, Harv. Douglas Bay (Brady),

P. urceolata, Grev. Port Erin, Port S. Mary. Douglas Bay (Talbot).

P. elongella, Harv. Port Erin, Douglas Bay (Mrs. Gatty, Talbot).

P. elongata, Grev. Port Erin, Douglas Bay (Talbot), Peel.

P. violacea, Wyatt. (With cystocarpia and gonidangia.) Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot).

P. fibrillosa, Grev. (With cystocarpia and antheridia.) Port Erin, Douglas Bay (Mrs. Gatty).

P. fastigiata, Grev. Port Erin, Port S. Mary, Fleshwick, Douglas Bay (Talbot), Peel.

P. atrorubescens, Grev. Douglas Bay (Talbot).

P. nigrescens, Grev. Port Erin, Port S. Mary.

P. parasitica, Grev. Douglas Bay (Brady, Talbot).

P. brodiaei, Grev. (With cystocarpia and gonidangia.) Port Erin, Port S. Mary, Douglas Bay (Mrs. Gatty), Peel.

P. thuyoides, Harv. Douglas Bay (Brady, Talbot).

P. fruticulosa, Spreng. Douglas Bay (Brady, Talbot), Port Erin.

**P. spinulosa*, Grev. Port S. Mary.

Lophothalia byssoides, J. Ag. (With cystocarpia and gonidangia.) Peel, Douglas Bay (Brady, Talbot).

Dasya coccinea, C. Ag. Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot), Peel.

D. arbuscula, C. Ag. Douglas Bay (Talbot).

D. ocellata, Harv. Douglas Bay (Talbot).

Ord. VI. CERAMIACEAE.

Spondylothamnion multifidum, Naeg. Kirk Onchan (Brady), Port Jack (Talbot).

Spermothamnion turneri, Aresch. Port Erin, Douglas Bay (Brady).

**Wrangelia multifida*, Ag. Peel.

Griffithsia corallina, C. Ag. Douglas Bay (Miss Thompson).

G. setacea, C. Ag. (With gonidangia.) Port Erin, Port S. Mary, Douglas Bay (Brady), Peel.

Pleonosporium borreri, Naeg. Douglas Bay (Mrs. Gatty), Port Erin.

Rhodochorton rothii, Naeg. Port Erin.

Rh. floridulum, Naeg. Port Erin, Douglas Bay (Mrs. Gatty).

Rh. membranaceum, Magn. Port S. Mary.

**Rh. mesocarpum*, Kjell. Port Erin.

Callithamnion polyspermum, C. Ag. Douglas Bay (Mrs. Gatty).

C. roseum, Harv. Douglas Bay (Talbot).

C. hookeri, C. Ag. (With cystocarpia and gonidangia.) Port S. Mary, Douglas Bay (Brady).

C. arbuscula, Lyngb. Port Erin, Port S. Mary, Douglas Bay (Talbot).

C. tetragonum, C. Ag. (With cystocarpia and gonidangia.) Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot), Peel.

C. tetragonum, var. *brachiatum*, J. Ag. (With cystocarpia and gonidangia.) Port Erin, Douglas Bay (Talbot).

C. corymbosum, Lyngb. Port Erin, Port S. Mary, Douglas Bay (Talbot).

C. granulatum, C. Ag. Douglas Bay (Brady, Talbot).

C. seirospermum, Griff. Douglas Bay (Miss Thompson).

C. byssoides, Arn. Kirk Onchan (Brady), Port Erin.

Compsothamnion thuyoides. Schm. Douglas Bay (Mrs. Gatty).

Plumaria elegans, Bonnem. Port Erin, Port S. Mary, Douglas Bay (Mrs. Gatty), Peel.

Ptilota plumosa, C. Ag. Port Erin, Port S. Mary, Douglas Bay (Mrs. Gatty).

Antithamnion plumula, Thur. Douglas Bay (Mrs. Gatty, Talbot).

**Ceramium gracillimum*, Harv. Port Erin.

C. tenuissimum, J. Ag. Douglas Bay (Talbot), Port Erin.

C. fastigiatum, Harv. Douglas Bay (Talbot).

C. deslongchampsii, Chauv. Port Erin, Port S. Mary, dredged off Contrary Head, Douglas Bay (Talbot).

C. strictum, Harv. var. *divaricata*, Holm. & Batt. Port Erin.

C. circinatum, J. Ag. Douglas Bay (Mrs. Gatty, Talbot).

C. rubrum, C. Ag. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

C. rubrum, var. *proliferum*, Ag. Douglas Bay (Talbot).

**C. rubrum*, var. *barbata*, J. Ag. Port Erin.

C. ciliatum, Ducluz. Port Erin, Douglas Bay (Brady, Talbot).

C. echionotum, J. Ag. Port Erin, Douglas Bay (Mrs. Gatty).

C. flabelligerum, J. Ag. Douglas Bay (Talbot).

C. acanthonotum, Carm. (With gonidangia.) Port Erin, Port S. Mary, Douglas Bay (Brady, Talbot).

C. diaphanum, Roth. (With cystocarpia.) Port S. Mary, Douglas Bay (Brady, Talbot).

Microcladia glandulosa, Grev. Douglas Bay (Talbot).

Cohort V. CRYPTONEMINAE.

Ord. I. Gloeosiphoniaceae.

Gloeosiphonia capillaris, Carm. Douglas Bay (Talbot).

Ord. II. Grateloupiaceae.

Halymenia ligulata, J. Ag. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Ord. III. Dumontiaceae.

Dumontia filiformis, Grev. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Dilsea edulis, Stackh. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Ord. IV. Nemastomaceae.

Furcellaria fastigiata, Lamx. Port Erin, Port S. Mary, Douglas Bay (Talbot).

Ord. V. Rhizophyllidaceae.

Polyides rotundus, Grev. Port Erin, Port S. Mary, Douglas Bay.

Ord. VI. SQUAMARIACEAE.

Petrocelis cruenta, J. Ag. (With antheridia.) Port Erin.

Peyssonnelia dubyi, Crn. Port Erin, Douglas Bay (Talbot).

**Rhododermis elegans*, Crn. Port Erin, Port S. Mary.

Ord. VII. HILDENBRANDTIACEAE.

Hildenbrandtia prototypus, Nard. var. *rosea*, Kütz. Port Erin, Douglas Bay (Talbot).

Ord. VIII. CORALLINACEAE.

Schmitziella endophloea, Born. & Batt. (On *Cladophora pellucida.*) Port Erin, Port S. Mary.

Melobesia confervoides, Kütz. Port Erin, Douglas Bay (Talbot).

M. pustulata, Lamx. Douglas Bay (Talbot).

M. membranacea, Lamx. (With gonidangia.) Port S. Mary, Douglas Bay (Talbot).

M. verrucata, Lamx. Douglas Bay (Talbot).

Lithophyllum lichenoides, Phil. Port S. Mary.

L. lenormandi, Ros. Port Erin.

Lithothamnion polymorphum, Aresch. Port Erin, Port S. Mary.

L. calcareum, Aresch. Dredged off Port Erin.

Corallina officinalis, L. Port Erin, Port S. Mary, Douglas Bay (Talbot), Peel.

C. rubens, Ell. & Sol. Port Erin, Port S. Mary, Peel.

C. rubens, L. var. *corniculata*, Hauck. Port Erin.

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EXPLANATION OF PLATE.

Fig. 1. *Isthmoplea sphaerophora* (Hauck.), Kjellm. Filament with gonidangia.

Fig. 2. *I. sphaerophora*, with gametangia.

Fig. 3. *Callithamnion tetragonum*, C. Ag. Branch bearing cystocarp, tetragonidia and antheridia.

Fig. 4. Vegetative cell of gonidangial filament.

Fig. 5. Vegetative cell of gametangial filament.

Fig. 6. *Polysiphonia violacea*, Wyatt. Branch bearing cystocarp and tetragonidia.

Fig. 7. *Ectocarpus* sp., with gametangia and gonidangia.

Figs. 3 and 6 are drawn under Leitz obj. III; figs. 1 and 2 under Leitz obj. VI; figs. 4, 5 and 7 under Leitz oil im.

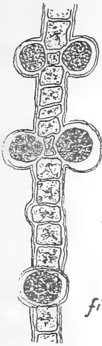

fig 1

fig. 2

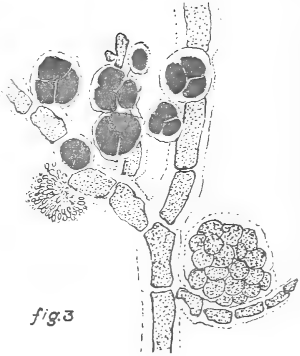

fig. 3

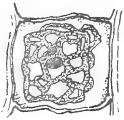

fig. 4

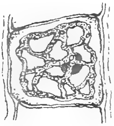

fig. 5

fig. 6

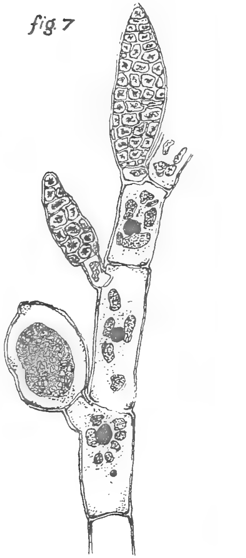

fig. 7

M. K. del.


M. AURELIJ SEVERINI
ZOOTOMIA DEMOCRITÆA

THE EARLY DAYS OF COMPARATIVE ANATOMY.

By F. J. COLE, D.Sc.,

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(Communicated February 14th, 1913.)

I feel I owe to the members of the Society some explanation, I had almost said apology, for selecting as the subject of this address, a topic the biologist so generally avoids as history. I must therefore endeavour to justify a venture which may appear to some both hazardous and unprofitable.

I

It is the necessity, but also the misfortune, of the man of science to focus his efforts on the field that lies in front, and to cast no "longing lingering look behind." Unlike other branches of study it would be invidious to mention, the biologist, so far as research is concerned, suffers from an embarrassment of riches. The untrodden paths are so numerous and inviting, and the temptation to add his small contribution to the sum of human knowledge is in itself so laudable, that he eagerly assumes the yoke of the pioneer, and rejects the wisdom which comes after the event. He doubts not the mission of his own generation, or the adequacy of the knowledge and methods he finds at his hand. What he fails to realise is that there is nothing new under the sun. That the same mental limitations which frustrated the observer of the XVII. century may defeat the investigator of to-day. The lack of balance, that just revenge of neglected knowledge, may destroy, in the loose thinking of an unguarded moment, the faithful observation of months.

Now the study of history, whilst it cannot exclude error, completes and rounds off the learning of the modern schools, and assists in keeping the worker within his limits. It carries him into a quaint and unaccustomed atmosphere. It flogs his imagination. He can foregather with men, surely as great as any now, and with this added advantage. He can see them as they really are, his judgment preserves its sense of proportion, and the genius of the old masters is neither magnified nor obscured by the closeness of the observer. When Robert Boyle approaches him and says—I have demonstrated the Spring of the Air, he replies—excellent, admitted, but *why* did you advise me to cure my complaints by frying a live toad on a shovel and hanging its ashes round my neck. In this common paternity of a great discovery and a fragment of romantic mediaevalism, we detect the rattle of the skeleton in the cerebral cupboard. The human mind is good only in parts, and the man of genius is discovered as mortal. Thus history teaches us to be cautious in honouring the drafts of authority, and to accept a statement, not because it is made by Galen, and endorsed by the Society of the Curious in Natural History, but because it is *sound*.

But there is another, and to me a greater, reason why the history of Biology should be cultivated. It introduces the element of *literary* interest, perhaps not the least important of the differences which separate the unimaginative from the creative artist. Philemon Holland's translation of Pliny's History of the World, published in 1601, is an education in the formidable combination of literature and science. The honours student who can be persuaded to mitigate the strong and occasionally contentious waters of modern biology with some such diluent will not deny the dissipation. We run a serious risk, as teachers, in neglecting the humane side of scientific literature, and the academic world has already incurred the contemptuous reproach of Edward Gibbon, who tells us that after he left the University his interest in books *began to revive*. He himself practised the wisdom of extending his mental horizon in every direction, and he attended a course of lectures on anatomy by Dr. William Hunter, the eloquent brother of the more famous John, with the result that we may "sometimes track him in our own snow."

II.

To insist that there can be no comparative anatomy without evolution, is to be bound by all the limitations of a strict and academic mind. For the elucidation of an organ in one animal by a comparison with the corresponding feature in another was practised in the earliest days of anatomy. The *explanation* of this community of structure is another story, although naturally a closely related one. The development of an idea may be slow and uncertain, and we must not expect, in groping underground for the roots of knowledge, to find the products which characterise a later growth in the freedom of the atmosphere. To rigorously distinguish, in the early days of anatomy, between a Zootomist, who merely dissected an animal, and a Comparative Anatomist, who resolved the evolution of its parts, is to apply a modern standard to an ancient work, and to deny that comparative anatomy has arisen by any process of natural growth with which we are acquainted. Who can doubt that in the following two cases, both of them long antecedent to the period of evolution—and one could quote many others—we have the origin and practice of a method which was to exercise the genius of a Cuvier and a Johannes Müller.

1. Belon in 1555 compares the skeleton of a man in some detail with that of a bird. Apart from a natural failure to identify the clavicle of the bird, and the consequent misinterpretation of the coracoid, together with some hesitation for which the elongated metacarpus is responsible, his comparison is correct at every point. The confusion of the radius and ulna in the figure is an engraver's error, since the text on this point is quite sound. In the leg of the bird, where we should have expected him to go badly astray, in the absence of any knowledge of its development, he only commits the venial error of mis-stating the extent of the tarsus, whilst he adroitly avoids the pitfall of comparing the tarsal joint with the knee, and of regarding the tarso-metatarsus as a new element. The bones of the bird, he tells us, approach those of other animals more closely than a casual inspection at first suggests.

2. Nehemiah Grew in 1681 compares the chambered stomach of the sheep with the stomach of man. He says: "The fourth venter is called Abomasus: by butchers, the Read. The only analogous one to that in a man."

That the early anatomists themselves understood and valued the method is abundantly clear. Again I might quote numerous instances, but four must suffice.

1. Malpighi in 1666 contrasts the state of anatomy in his own time with the knowledge of the ancients, and attributes the superior genius of contemporary anatomy to the investigation of the Invertebrate and lower Vertebrate animals, as opposed to the practice of the

ancients, who confined their work rather to the higher forms of life.

2. Samuel Collins in 1685 says: "And I humbly conceive the great use of comparative anatomy is to illustrate the structure, actions, and uses of man's body, which are sometimes more clear in that of other animals, than in ours; as I have discovered in frequent dissections to my great satisfaction, pleasure and admiration."

3. Alexander Pitfeild in 1687 observes that as regards "the Construction, Fabrick, and Genuine Use of the Parts of Animals, and even of Man: A Knowledge no way better to be obtained than from the Comparative Anatomy of divers Animals; that Texture of Parts being discoverable in one Animal, which Nature has conceal'd and made more obscure in another."

4. Edward Tyson, in his scholarly work on the anatomy of the Chimpanzee, published in 1699, remarks: "To render this Disquisition more useful, I have made a *comparative* Survey of this Animal, with a Monkey, an Ape, and a Man. By viewing the same Parts of all these together, we may the better observe Nature's Gradation in the Formation of Animal bodies, and the Transitions made from one to another; than which, nothing can more conduce to the Attainment of the true Knowledge, both of the Fabrick, and Uses of the Parts."

Here we may enquire when the expression Comparative Anatomy first appears in the literature of Biology. In 1675 Grew published a tract entitled "The Comparative Anatomy of Trunks" [of trees]. This was reprinted during his own lifetime, and under his supervision, in 1682, when the word comparative, for some unexplained reason, was erased. In the meantime, in 1681, he had also issued "The Comparative Anatomy of Stomachs and Guts begun," in which he again commits himself to the same expression. In 1675 Nicholas Hoboken uses the expression "anatomia comparata" in his work on the anatomy of the seal, and earlier still, in 1672, it is employed by Thomas Willis in his treatise on the Soul of Brutes. It is curiously difficult to be certain on a point such as this; but I imagine that Walter Charleton, in the first edition of the Onomasticon Zoicon, published in 1668, was the first to distinguish "Anatomia comparativa" as a branch of Biology.

III.

This is neither the time nor the occasion to explore the work of the ancients. Aristotle has been sufficiently expounded, and we can only hope that Galen will soon achieve an English commentator and an English dress. That his work is partly, if not largely, comparative does not require for its demonstration the methods of the higher criticism. When he says that the lower jaw is in two halves, that there is a separate premaxilla, that there are eight segments in the sternum, that the transverse processes of the lumbar vertebra are directed forwards, that the sacrum and coccyx have three pieces each, and that the femur is curved, he is *not* describing the anatomy of man. His apologists in the sixteenth century exhausted all the resources of desperation in his defence as a human anatomist, and it was seriously claimed by Sylvius that the structure of the human body had *changed* since the time of Galen. The explanation of this assumed change was itself eagerly debated, and it is difficult to acquit the Galenists of levity in ascribing the straight femur of man to the substitution for the airy freedom of the toga of the cylindrical garments of a later age.

But it must not be concluded that the outstanding figures of Aristotle and Galen exhaust the list of the ancient anatomists. Anaxagoras dissected the head of a Ram, Empedocles examined the structure of many animals and discovered the cochlea of the ear, whilst Alcmaeon practised the undesirable combination of erotic poetry and anatomical study. Among the lesser lights of anatomy, however, Democritus occupies a unique position. We know, on the somewhat doubtful authority of the elder Pliny, that he dissected the Chameleon, and "verely made so great reckoning of this beast that hee compiled one entire booke expressely of it and hath anatomized everie severall member thereof." There is also a strong tradition, but a lack of convincing evidence, of a meeting between Democritus and Hippocrates. The legend does not gain in credibility by the fact that modifications of it introduce the persons of other actors such as Aristotle and Heraclitus. It is interesting as an "abuse of the privilege of fiction," but also because it is the subject of the engraved title of almost the earliest comprehensive treatise on comparative anatomy we have—the Zootomia Democritaea of Severini. The laughing philosopher, having retreated from the world to pursue his studies among the amenities of the neighbouring cemetery, becomes the object of the contempt or pity of the citizens of his native Abdera. They draft a letter, of which the extant copy is a mediaeval forgery attributed to Epictetus, invoking the assistance of the Father of Medicine. The engraving represents in the background the lively distress of the simple Abderitians, whilst in the foreground we observe Democritus, seated in what appears to be a butcher's shop, awaiting the composed and stately figure of the physician. He is asked why he occupies himself in the dissection of the viler creatures, and he replies in philosophic idiom that his object is to discover the cause of folly, the seat of which he suspects is in the bile. The conference speedily establishes the wisdom and sanity of the patient, and Hippocrates retires to allay the anxiety of the citizens. Or in the expressive language of Severini—" Says Hippocrates, 'By Jove, O Democritus, thou speakest truly and wisely.' "

Between the decline of classical learning and the invention of printing at the middle of the fifteenth century, we search with little success for any example of comparative anatomy, and this period is represented almost exclusively by one small work—the Anatomia Porci of Copho. Details of the life of Copho are entirely wanting—we do not even know which of the two men of that name is responsible for the Anatomia, but judging from contemporary references it must have been written before the end of the thirteenth century. This little tract, which extends to only a few pages of type, may be traced through eleven printed versions ranging from 1502 to 1852. It is a work of little merit or distinction, and there are no illustrations. Its interest lies not so much in what is disclosed, as on the light it throws on the state of biological science at the time it was written. And in comparing it with the mass of accurate and detailed anatomy collected centuries before in the works of Galen, we lament the total eclipse of the republic of letters during the era known as the dark ages.

Copho addressed himself to the internal anatomy of the pig, as he tells us, because of its resemblance to that of man, and he claims that the same reason explains the comparative researches of the ancients. His point of view is clearly that of the physician, and we gain the impression that he has taken to anatomy as a doubtful and irksome necessity. He describes in a brief and elementary manner the anatomy of the mouth and of the chest and abdomen. He mentions the larger vessels, and demonstrates the alveolar nature of the lungs by inflating them with a quill.

IV.

That ill-defined and shifting upheaval which resulted in the revival of learning produced little effect on the biological sciences, which lagged far behind as if dependent on the invention of printing. In comparative anatomy the revival of research may be dated from the memoirs published in 1573 and 1575 by Volcher Coiter, the "excellent friend" of Eustachius, and a product of the school of Padua, one of the first and certainly the greatest of all schools of anatomy. The grip of the middle ages no longer paralyses the energies of the observer, and the works of Coiter challenge the understanding and accuse the ignorance of his generation. Apart from the inevitable description of the development of the chick, a subject which has excited the curiosity of naturalists from the time of Aristotle, Coiter compares the skeleton of man with that of a higher and lower ape, and again with that of a fox. He is disposed to fasten rather on points of difference than to emphasize homologies. He deals with the skeleton and soft parts of all classes of Vertebrates except Fishes, and his section on the anatomy of Birds is especially admirable. He describes in remarkable detail, and illustrates with well-drawn figures, the complex tongue and hyoid of the woodpecker, the internal organs of Birds, their skeleton and muscles, and he explains how the pectoral muscles are used in flight. He adds to his achievements a scheme in which the classification of Birds is attempted almost for the first time.

A contemporary of Coiter's, but one who considerably outlived him, was Jerome Fabrici, a name grateful to Englishmen as that of the teacher of William Harvey, and who, by demonstrating the valves of the veins to his English pupil, played no inconsiderable part in the discovery of the circulation. He is almost the last of the great Paduan anatomists. The decline of the school, already apparent in his own time, made fatal progress in the next two generations, and Spigelius was the last of the old anatomists of Padua whose reputation extended beyond the common room of his own University. But Fabricius was the most famous teacher of anatomy of his day, and students assembled from the whole of Europe to profit by his lectures and demonstrations. The University paid him the sincere and grateful compliment of building what was regarded as an "ample and splendid" theatre to accommodate his large classes—a gloomy and unsuitable erection which has happily survived the censure of posterity. Time has failed to endorse his abilities as worthy of the great traditions of his chair, and it is difficult to forgive, though it is easy to understand, the lack of enterprise which handed over to a pupil a discovery properly his own. And as a comparative anatomist Fabricius shines with no steadier light. The conspicuous example of self confidence and independent judgment provided by his most illustrious predecessor in the chair of anatomy at Padua does not inspire him to trust in his own genius and fortune, and to bring a severe and critical faculty to bear upon the writings of the ancients. His respect for classical authority, in accordance with the most conservative traditions of the human mind, is constantly at variance with the evidence of his own senses. He moves forward, he hesitates, he looks back, he is overwhelmed by the misery of doubt and distraction. Yet it must not be concluded that he failed to achieve results both interesting and important. He compares the skeleton of the limb of the horse and man, and corrects the old and natural blunder of the position of the knee and elbow. He writes on the comparative anatomy of the hyoid bone and of the gut, and I ought specially to mention his striking work on the comparative anatomy of the eye, ear and larynx, published at Venice in the year 1600, in which he compares in detail the skeleton and muscles in a number of animals, mostly mammals. He was a skilled, and almost a great, technician, and if we are to distinguish in these early days between a zootomist and a comparative anatomist, Fabricius must be assigned an honourable position among the first explorers of the former school.

V.

But the sixteenth century reserved for its close the brightest achievement of an awakening science. As if anatomy were in the air there appeared at Paris in 1594 a small and imperfect treatise by Jean Héroard on the osteology of the horse, and almost immediately afterwards Carlo Ruini, a senator of Bologna, issued his volume on the anatomy and diseases of the same animal. It is to be regarded as the logical outcome of the Vesalian tradition, and it resembles, but does not equal, the masterpiece of the founder of anatomy in almost every detail. Like the Fabrica of Vesalius, it set a standard which posterity could only approach by working up painfully to it from below.

It is instructive to the genius of a speculative age to trace the parallel between these two works. In both cases we observe an inflexible determination to exhaust the anatomy of one type, and to avoid vain and argumentative digressions by the way. And it is significant that whenever the author turns aside from this high determination, he becomes involved in disaster. Thus Vesalius in a parenthesis on the skull of the crocodile tells us that the lower jaw is fixed and that the upper jaw moves—a statement which recalls an equally misguided belief on the part of Oliver Goldsmith. Ruini, in his turn, becomes entangled in a greater snare when he describes a backward flow of blood along the veins. Ruini's work, as we should expect from the cumbrous nature of his subject, is more topographical than Vesalius', but as far as possible he goes through the animal system by system in the same patient and exhaustive manner. We know the anxiety of Vesalius to secure the best illustrations available at the time, how he employed a pupil of Titian's to make the drawings and engrave them on wood, and how he indulged a whimsical, and not always amiable, fancy of throwing his figures into attitudes and providing them with a rustic setting. In all this Ruini is his close, and not always successful, imitator, although the last figure of the muscles of the horse in Book V. is a work with distinct artistic feeling. You have only to compare it with any of the pirated copies engraved on copper to realise, in spite of its coarseness, the superior merit of the original figure. Both anatomists suffered from scandalous and shameless plagiarism. Their successors, lacking the ability to excel or to extend, frankly adopted the infamous alternative of theft. There are several pirated French versions of Ruini, including the Perfect Cavalier, and Saunier's Complete Knowledge of the Horse. In England, Snape's Anatomy of an Horse, first published in 1683, is little more than a plagiarised translation of Ruini brought up to date, and the figures, with a few exceptions, are close copies of most of his plates, without any mention of his name. In one instance Snape acknowledges that the figure is "taken out of a French authour," which seems to indicate that he was himself, like the receiver of stolen goods, ignorant and careless of the real owner of the property. In another plate the only original feature of importance is the addition of a dragon-fly to the background, and finally a caricature of Ruini's not very successful figure of the entire skeleton is stated to have been "drawn exactly by one that I keep standing in a Press." Snape's introduction can only be regarded as a reckless exhibition of mendacity, which calls for the condemnation of posterity. He boldly assumes the laurels of a pioneer, and claims that none have gone before or showed him the way. In submitting the merit of the figures he says: "I have therefore accordingly by a curious draught or delineation represented to you such observations as are made in true dissections," and again, in discussing the relative merits of books and dissections, he discovers an unconscious vein of candour when he urges the student "not to trust too much to these *copies*, as I may call them, without practicing upon the original body itself." The whole transaction, and the early literature of Biology affords many such, recalls the indignant rhetoric of Dr. Knox: "As to the hack compilers, their course is simple: they will first deny the doctrine to be true; when this becomes clearly untenable they will deny that it is new; and they will finish by engrossing the whole in their next compilations, omitting carefully the name of the author."

Ruini's treatise, which passed through fourteen editions from 1598 to 1769, but which is nevertheless little known, is divided into five books, each with its own series of wood engravings. The original edition is now very scarce. The first book deals with the anatomy of the head generally, and includes the skull, the muscles and vessels, the teeth at different ages, the brain and its membranes, the sense organs, and the mouth and tongue; book II. is concerned with the neck and thorax, its skeleton and muscles, the hyoid and larynx, the nerves and vessels of the neck, the heart and lungs and the diaphragm; book III. relates to the abdominal contents and tail, the gut and its glands, mesentery and peritoneum, renal organs, the great vessels of the abdomen, the vertebral column and skeleton of the pelvic region, and we note also a scheme of the portal vein clearly inspired by that of Vesalius; book IV. is an account of the genital organs in both sexes, the development of the horse, and the structure of the foetus and placenta; book V. completes the work with a detailed description of the topographical anatomy of the fore and hind limbs, to which he has evidently given close attention, and in addition there are seven figures of a general character summarising the more important features of the skeleton, veins and arteries, nerves and muscles. The schemes of the arteries, veins and nerves recall the least inspired and convincing efforts of Vesalius.

VI.

The transition from the monographic to the systematic treatment of animal anatomy is a step so familiar to the modern anatomist that the slow and halting movements of the old masters arouse only his wonder and contempt. The possibilities and importance of monographic anatomy had been successively demonstrated, one might almost add exhausted, by Galen, Vesalius and Ruini. The limitations of work of this character were apparent to Coiter, and he endeavoured according to the measure of his ability to introduce the new element of philosophic enquiry and discussion. But it is difficult to make the dry bones live, and even when the first step has been taken towards the possibility of a second, and the second itself is in fact impending, the tyranny of tradition may for a time inhibit a departure which is none the less inevitable. So it was with comparative anatomy. The first step had been brilliantly accomplished, but the expected advance was still delayed.

In the meantime some tentative efforts were being put forth. Early in the seventeenth century Casserius—first the domestic servant, then the pupil, and finally the successor of Fabricius at Padua—had published his works on the organs of sense and voice. He definitely repudiates the practice, which, owing to the influence of Fabricius, was no longer rigidly observed, that human anatomy should constitute the only charge on the time of the Professor, and his two works owe their value to the fact that they are largely comparative. He was however less a philosopher than a practical anatomist, and his text, which is marred by various errors, does not attain the level of his plates. But he does achieve the distinction of endeavouring to explain the fabric of man by appeals to the lower animals, and that the fundamental principles of comparative anatomy were feebly stirring in his mind, an examination of his writings establishes beyond question.

The clear and penetrating intellect of William Harvey, the immediate successor in time of Casserius, enabled him to leap the gap. His own procedure is well known—he *urges* the necessity of comparative studies.

He holds that an Insect is worth investigating in itself, but still more for what it suggests of the greater truths of biological science. In the strict academic sense we recognise in Harvey the first comparative anatomist. He seizes every opportunity of illustrating his views, and stimulating his imagination, by reference to the viler creatures, as he calls them, and the beating of the heart of an Amphipod is not only interesting as such, but to him it throws a powerful light on the beating of the heart in man. He says: "Had anatomists only been as conversant with the dissection of the lower animals as they are with that of the human body, the matters that have hitherto kept them in a perplexity of doubt would, in my opinion, have met them freed from every kind of difficulty."* Nothing could be plainer. Here we have the whole practice and rationale of comparative anatomy divulged in the year 1628.

Unfortunately the greater part of Harvey's researches on comparative anatomy, and they must have been considerable, were lost or destroyed in the unhappy tumults of the Civil War. He used to tell John Aubrey that of all the losses he had sustained no grief was so crucifying to him as the loss of these manuscripts, and, as it is, his published work contains new observations on sponges and zoophytes; bees, wasps, hornets and flies; mussels, snails, and slugs; crabs, shrimps, and crayfish; fishes, toads, frogs, serpents, tortoises and birds. Even his study in generation, based as it is largely on the chick, includes numerous acute and original references to other animals, and is thus the first essay in comparative embryology.

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* Willis's translation. "Veruntamen, si in dissectione animalium aeque versati essent, ac in humani cadaveris anatome exercitati: Res haec in dubio, quae omnes perplexos retinet, palam absque omni difficultate mea sententia elucesceret." *De Motu Cordis*, first ed., 1628, p. 33.

But of all the undertakings stimulated by the varied activities of the seventeenth century none discovers our interest more than the Zootomia Democritaea of Severini, published in 1645. As a surgeon he favoured the stern and ruthless school of iron and fire—a school of the blackest mediaeval cast, surrounded by all the terrors of torture and mutilation. We search in vain in his animal anatomy for the strength and boldness which his reputation as a surgeon would lead us to expect. He is crude, diffuse and superficial, his descriptions are often mere catalogues of the coarser anatomical facts, and many of his figures are so original as to be unlike the objects they represent. His work might have been written in the preceding century, before the possibilities of anatomy had been revealed by Vesalius. Not that he is unfamiliar with the works of his predecessors, all of whom are quoted with the surprising and important exception of Ruini. It is at once gratifying to our national pride, and illustrative of the expansive powers of true genius, that Severini should have been an almost exact contemporary of William Harvey.

Human and comparative anatomy are distinguished by Severini as Andranatomy and Zootomy. In a long general section, which embraces also the anatomy of plants, he recognises the unity of the Vertebrate animals, including man, and regards divergences from the type as due to disturbances of function. The general similarity he attributes to Divine design. In comparing the anatomy of the ape and man he considers their affinity so patent that the ape should be exploited for medical purposes, and therefore stress is laid only on the points of difference. He is not misled by the specialised character of birds, but here he appears to have been ignorant of the work of Belon. Man is regarded, conformably to the humour of his time, as the "archetype" of all animals. The superficial resemblance of the Viper and the Eel entraps him into arranging their distinguishing features in parallel columns, but he is evidently in doubt himself, and the reader is left to draw whatever conclusions he can from this irregular alliance. He pursues in some detail the anatomy of most orders of mammals; of birds, fishes and cephalopods; and there are in addition observations on tortoises, lizards and snakes; frogs and toads; insects and arachnids; crayfish, slugs and snails; and earthworms. A section on anatomical methods concludes the treatise. As examples of the matter and scope of his work, he understood the structure and physiology of the complex stomach of Ruminants, and he describes the well-developed sclerotic of separate bony plates in the birds of prey.

VII.

The constitution of the French Academy of Science in 1666 established a school of morphology to which the modern development of comparative anatomy may be directly traced. The Academy divided its forces into Mathematicians, who met on Wednesdays, and Physicists, as Biologists were then called, who met on Saturdays. As we gather from contemporary engravings, and from the reports of their proceedings, the Academy in no sense corresponded to the scientific society of to-day, but was rather a *laboratory* for the practical examination and discussion of natural phenomena. We note with satisfaction, but with little surprise, that in the subsequent decline of the Academy up to its reconstitution in 1699, the biological section alone retained its vitality, and the earnest and virile band of comparative anatomists were never disposed to calculate the odds of a game of chance, or to exercise their genius on the details of ornamental gardens. The longevity of a public man is variously ascribed, according to the prejudice of the critic, to the reward of virtue or to a supernatural evasion of the justice of Heaven, and the remarkable longevity of the early Parisian anatomists, only one of whom died before the age of 75 years, may well provoke the doubts of the irreverent mind. Their leader was Claude Perrault, a member of a versatile family, who abandoned the profession of arms for the pleasures of art, and became one of the leading architects of his age. But he is no less distinguished as an anatomist and a physician, and it is mainly to his influence that a number of the early members of the French Academy, who are usually referred to in contemporary literature as the "Parisians," initiated a movement which has since been actively and continuously developed. The principal members of the "company" were the "acute and lucky Pecquet," as Robert Boyle used to call him, Louis Gayant, the great figure of Duverney, Moyse Charas, and the Jesuit Father Thomas Gouye. It is a commonplace both in literature and science that a great book seldom fails to attract an adequate illustrator, and the Parisians were fortunate in enlisting the services of Sébastien Le Clerc, again a well-known architect, and an engraver on copper of outstanding merit. Only some of the plates are signed by Le Clerc, but there are no peculiarities of execution sufficient to justify the belief that other engravers were employed. Of the numerous subsequent editions none approach the first in the excellence of the illustrations, and it is therefore all the more unfortunate that so few copies were printed, since the work is now practically unobtainable. We learn from Alexander

Pitfeild that it had become very scarce even in the seventeenth century, and in recent times only one copy has come into the market for many years.

At the risk of obscuring the main issue in a cloud of detail, I am tempted to give a brief history of the publications of the Parisians, the bibliography of which beguiled the leisure of several weeks. Their first venture was the anonymous issue of a small tract of 27 pages and two plates, published at Paris in 1667. They had dissected a "large fish" [*Alopias vulpes*] on June 24, 1667, and a Lion on June 28 of the same year, and the tract contains a description of their results. Two years later they published a larger work of 120 pages and five plates, dealing with the anatomy of a Chameleon, a Beaver, a Dromedary, a Bear and a Gazelle. They were now definitely committed to a more ambitious enterprise, and, encouraged by the interest which these papers had aroused, they projected an extensive work on comparative anatomy on a scale not hitherto attempted. This was published anonymously, at the expense of the King, in two sections in 1671 and 1676, but in the latter year both sections were issued together with Perrault's name on the new title page. The preparation of the work was begun by Perrault, Pecquet and Gayant, and the material they employed had died of sickness in the Royal Menagerie mostly during the winter months. Gayant died in 1673 and Pecquet in the following year, but the work not being completed, Duverney was happily invited to assist in the final stages, and his services are specially commended by Perrault. In 1680 the "Essais de Physique" were published by Perrault—a work which passed through several editions, and which includes numerous observations on comparative anatomy.

The death of Perrault, which occurred in 1688, left

Duverney in charge of the conduct of the work, but for some reason which is still obscure he failed to apply himself vigorously to the discharge of his trust. He discovered among Perrault's papers descriptions of sixteen new animals, but he refrained from publishing them, and his attempt to bring out a new edition of the series only resulted in the publication of the first section in the year 1700. Urged by the Academy to greater efforts, he undertook the preparation of a revised and extended edition in 3 vols. quarto, but he died in 1730 before this could be accomplished. The duty was then entrusted by the Academy to Winslow, Petit, and Morand, who examined the papers bequeathed to the Academy by Duverney, compared them with previous editions, and completed their task by December, 1731. They included the sixteen unpublished descriptions of Perrault, and added a chapter on the Viper by Charas, which had appeared separately in 1669. A fourth volume based on material left by Duverney, Méry, and Lahire was not completed, and Duverney's work on the anatomy of Fishes is still unpublished.

In 1686 and 1689 Father Tachard published descriptions of the two missions dispatched by the Jesuit Fathers to Siam. The fathers interpreted their mission in a liberal and catholic spirit, and they supplemented their sacred duties by observations on the natural history of the country. Many animals were dissected on the spot, and others were forwarded to Paris, where they aroused the lively interest of the members of the Academy of Science. In this way the Academy received in 1687 a Crocodile, Tarentola [*Platydactylus*], a Camel and a Tiger, and the anatomy of these animals by Father Gouye is included in the edition of the memoirs we are now considering, which was at length published in

1732-1734. This, therefore, is the most complete edition of the monographs of the Parisians, and it is happily not difficult to obtain, although it cannot compare in interest or execution with the first complete edition of 1676.

The booksellers of the seventeenth and eighteenth centuries provoke the resentment and tax the labour of the bibliographer by their loose methods of publication. In the first instance the sheets were printed and issued under the name of the responsible agent, but he retained the right of farming them out to all who chose to apply for them, the purchaser being permitted to print a new title, and to publish the work from his own town, and under his own name and date. This procedure was naturally exploited for the profit of the unscrupulous, and the case of Dr. William Cowper, who purchased 300 copies of the sheets of Bidloo's atlas, and sold them under his own name *as author,* is familiar to students of the history of anatomy. Thus it comes about that the same work may be published a number of times, from many centres, and under a variety of dates. Copies even of the same issue may bear varying dates, an altered date, or no date at all. The conscientious bibliographer, who sees his leisure slipping away from him, but who dare not assume the identity of editions he has not personally examined, can only arraign the practice and submit to his fate. And it does occasionally happen that he is rewarded by some small detail he must otherwise have missed. The monographs of the Parisians are a tedious example of this pernicious custom, and I doubt whether, even now, I have unravelled *all* the ramifications of this sprawling publication. After the issue of the completed first edition in 1676, another edition was published at Paris in 1682. The first English edition appeared in

1687, the text translated by Alexander Pitfeild and the plates re-engraved by Richard Waller, whose engraved title was plagiarised in Valentini's Amphitheatrum Zootomicum in 1720. Unhappily the English plates are little better than caricatures of the finished engravings of Sébastien Le Clerc, but we must not forget that they represent the maiden efforts of the engraver. An imperfect French edition, together with Father Gouye's independent observations, appeared in 1688. Then follow numerous issues, some of them incomplete, in English, French, Dutch and German down to 1758, when the work ceased to be printed after a life of almost a century. As an illustration of the fatigues and surprises of this bibliographic chase, I have in my own library an English edition dated 1701, of which no other copy can be traced—a circumstance which combines features of satisfaction and despair.

In the just applause of their own discretion the Parisians happily disclose their methods of work. The dissections were carried out, not by any individual, but in session of the whole company, and nothing was committed to paper which failed to command the ready assent of all present. They say: "That which is most considerable in our *Memoires* is that unblemishable evidence of a certain and acknowledged Verity. For they are not the work of one private person, who may suffer himself to be prevail'd upon by his own opinion" . . . . "This so precise exactness in relating all the particulars which we observe, is qualified with a like care to draw well the figures, as well of the entire animals, as of their external parts, and of all those which are inwardly concealed. These parts having been considered, and examined with eyes assisted with *Microscopes*, when need required, were instantly designed by one of those upon whom the Company had imposed the charge of making the descriptions; and they were not graved, till all those which were present at the dissections found that they were wholly conformable to what they had seen. It was thought that it was a thing very advantagious for the perfection of these figures to be done by a hand which was guided by other sciences than those of painting, which are not alone sufficient, because that in this the importance is not so much to represent well what is seen, as to see well what should be represented.'' Characters presenting no feature of special interest are hardly more than catalogued, but they explore with patience and curiosity any departure from the commonplaces of anatomy, such as the compound stomach of the Gazelle, and the claws of the Lion. Their limitations are well defined, and not always consistent. They expect too close an agreement with the human type, a belief which constrains the imagination without preventing error, for they deny, after only a casual inspection, that the chamaeleon has an ear. Their lack of familiarity with the microscopical method introduces other difficulties, and they hesitate to distinguish between the kidney of the chamaeleon and its testis. Repeated efforts are made to link up structure and function. Thus they endeavour to associate the production of voice with a vertical glottis, and its absence with a transverse one—an essay in philosophic anatomy after the manner of Aristotle.

It would be improper to take leave of the work of the Parisians without some statement of the range of their investigations, and of the results they achieved. And in doing so I shall confine myself to the first complete edition, the extended later issues belonging to another period and generation. The animals were dissected and described in the order in which they fell into their hands, and no attempt is made to classify them. The Parisians are careful to identify their examples, and adequate space is devoted to this; but they are above everything committed to anatomical research. Over 30 species are described, and the groups represented are those commonly drawn upon in stocking a menagerie. The species include 1 Elasmobranch, 1 Chamaeleon, 1 Chelonian, 8 Birds, 1 Insectivore, 2 Rodents, 8 Carnivores, 7 Ungulates, and 2 Monkeys.

In the Lion they detected the independent blood supply of the cortex and medulla of the kidney, and an examination of the human kidney from the same point of view revealed a similar phenomenon, contrary to the statements of Vesalius. This they establish by injecting the veins with milk. The anatomy of the Chamaeleon is treated at length. They note the structure of the curious eyelid, and draw attention to the old error of attributing co-ordinated movements of the eyes to the optic chiasma, or the "joining of the optic nerves," as it was then called, for they found a chiasma in the Chamaeleon—an animal with remarkable powers of independent movement of the eyes. The stiffness of the neck is held responsible for this free and antagonistic behaviour of the eyes. They describe the unusual character and extent of the lungs, and inflated them through the trachea. The anatomy of the tongue claims a large share of their attention, and they observed how it was used in feeding. Their discussion of the mechanism of the tongue, however, is highly ingenious, but unsound. It is nevertheless interesting to note that the protrusion or erection of an organ, such as the tentacle of the Snail, in response to *vascular pressure* rather than to muscular contraction, was familiar to these seventeenth century anatomists. But the tongue of the Chamaeleon is *not* an example of this effect.

The lobulated kidney of the Bear, composed of 56 sub-divisions, each having its artery, vein, and efferent duct, is compared with the 10-lobular kidney of the Otter, and contrasted with the superficially lobulated kidney of the Porpoise and the newly-born human infant, which are stated to be essentially parenchymatous. The figures of *Alopias vulpes* are poor, but the description is accurate. The boundaries of the different regions of the gut are correctly defined, the distal limb of the stomach and the extent of the duodenum and rectum being determined on morphological criteria. The Parisians usually refer to the work of their predecessors, but they appear to have been unaware that the spiral valve had been already described by Severini. They give a good account of the heart and its valves, and note the backward extension of the nerve of the lateral line. The anatomy of the castoreum of the Beaver is accurately and minutely explained. It is distinguished from the scent glands of the Civet Cat, which are regarded as secondary sexual characters. They establish that the castoreum is not a reproductive gland, as formerly believed. Their only failure of importance is to miss the smallest sub-division of the second pair of glands, but on the other hand they note the difference in structure between the two sets of glands, and find also a difference in the character of the secretion. They point out, both in the Beaver and in the Civet Cat, that the contents of the glands have been produced *by the action of the gland tissue on the blood*—one of the earliest declarations of a physiological doctrine of supreme importance.

In the Seal they are again attracted by the lobulated nature of the kidney, which, with its superficial plexus of vessels, is satisfactorily dealt with, but the investigation of the heart involves them in unexpected confusion. They are of course aware that the Seal is not a fish, and cannot breathe under water. They are also aware that in the Mammalian foetus blood is diverted from the right side of the heart to the left through the foramen ovale in order to avoid the lungs, and they draw from this the fatal conclusion that the foetus does not respire. They profess to have found, and, indeed, may actually have found, a persisting foramen ovale in the heart of the Seal, and they believe that when the animal dives, and remains some time below water, the circulation follows the same course as in the intra-uterine embryo. The fact that the Seal is only below water for a relatively short time, whilst the circulation in the foetus remains the same throughout foetal life, should have warned them of the risk of assuming an interruption in the normal circulation every time the breathing organs were cut off from the atmosphere.

The Parisians describe for the first time in the Barbary Cow the valves in the primary hepatic branches of the portal vein, which are correctly interpreted as preventing the reflux of blood into the parent vein. These valves are not present in man. But a still more remarkable vascular phenomenon is discussed in the Stag, where the external and internal jugular veins are stated to possess sixteen valves disposed in six rows, the cavities of the valves being directed, not towards the heart, but *towards the head*. They fully recognise the unusual and incredible nature of this arrangement, which is explained as preventing "the too great impetuositie of the bloud which falls in its returne from the brain into the axillary branches." I am not aware that this statement has ever been confirmed or denied, and it is of course possible that the Parisians were mistaken in their facts.

The ancients were induced by the apparent affinity of the Hedgehog and Porcupine to unite them under the one genus of *Echinus*, but the Parisians, after anatomising examples of both animals, conclude that they are "very different," both as regards external characters and internal organs. But they go further than that, for they recognise the true affinity of the Porcupine with such forms as the Hare and the Beaver, and the large Rodent caecum of the Porcupine is contrasted with the reduction of that organ in the Hedgehog. By ligaturing the thoracic extremity of the azygos vein, and inflating it backwards, they establish a posterior anastomosis with the iliac vein, as in man—a point of detail we hardly expect at this early period. The large glandular vesiculae seminales of the Hedgehog, however, naturally overtax their knowledge and experience, and they interpret them as vascular organs for the elaboration of the blood before it reaches the testes.

The chapter on the Monkey only calls for comment as regards the description of the laryngeal region. Its close resemblance to the speaking larynx of the human species is converted into an agreement so exact as to emphasize dramatically the splendid isolation of man, and to concentrate the philosophic genius of the company on the happy but speechless monkey. They say: "For the ape is found provided by Nature of all these marvellous organs of speech with so much exactness, that the very three small muscles which do take their rise from the apophysis styloides, are not wanting, altho this apophysis be extreamly small. This particularitie do's likewise shew that there is no reason to think that agents do performe such and such actions, because they are found with organs proper thereunto: For according to these philosophers, apes should speake, seeing that they have the instruments necessary for speech." An opening such as this could hardly fail to provoke the ingenuous advocates of God-made man, and consequently we find Tyson, in confirming the statements of the Parisians, drawing an inference which he says the "Atheists can never answer." Yet neither the Parisians nor Tyson could be expected to comprehend those structural refinements which alone can evoke the harmony of speech, and it was reserved for the more instructed vision of Camper to supply a profane but convincing explanation of the silence of the forest.

The structure of Birds early engaged the more serious attention of the old anatomists, and it is therefore in accordance with tradition that the most complete and accurate section of the work of the Parisians is that devoted to Birds. They detect the connection between the calibre and length of the gut and the character of the food, and they note also that the absence and relative development of the caeca are determined by the same factor. They describe the sinus rhomboidalis of the spinal cord, first in the Eagle, and afterwards extend the discovery to other birds. Its contents are found to be a "white and glutinous humour," the removal of which by a duct is considered to be possible. The pecten of the eye is investigated and described in several birds, and its pigmented and vascular nature is clearly perceived. The pecten is supposed to be wanting only in *Apteryx*, but the Parisians were unable to find it in the Numidian Crane. They undoubtedly anticipate the modern view that the function of the pecten is the "nourishment of the humours of the eye." In the Cormorant they note the absence of the caeca formerly believed to be present in all Birds, and their description of the curious stomach is excellent. Although it differs markedly from the type usually present in Birds, they nevertheless distinguish a glandular portion, corresponding to the proventriculus, and a muscular portion, corresponding to the gizzard. Its unusual form they attribute to the piscivorous diet of the species.

But the bird most grateful to the curiosity of the Parisians, and of which they dissected eight examples, is the Ostrich, and they give a lengthy and excellent description of its anatomy. They pursue in detail the structure of the feathers, and contrast them with the quill feathers of a flying bird. In this they appear to have been ignorant of the work of Robert Hooke on the morphology of feathers, first published in the Micrographia of 1665. They understood the structure and function of the barbs and barbules, and they recognise the double advantage of a concavo-convex feather—its greater rigidity and grip of the air on the downward beat, and its diminished resistance on the upward stroke. They devote ample space to an account of the air sacs, which is on the whole complete and accurate, and they understood the connection between the air sacs and the lungs, and how they became filled with air. They regard the partitions separating the air sacs as a series of diaphragms, and we note with regret a tendency to go back on their acceptance of the doctrine of the circulation in the description given of the passage of the blood through the lungs. In the section on the brain an incident is mentioned which illustrates how the abuse of advertisement betrayed the confidence of mankind in a trusting and superstitious age. To demonstrate the powerful virtues of a healing balsam, its inventor would plunge a knife into the head of a bird, whose life he then professed to restore by the application of his celestial ointment; and provided the knife had been thrust into the fissure between the cerebrum and the cerebellum, the position of which the operator had prudently explored by private dissection, a miracle was duly proclaimed by an amazed and unsuspecting public.

In the Cassowary they describe and figure the long aftershaft of the feathers, and note the peculiar nature of the stomach and its valve, although the dilated duodenum is misinterpreted as a second chamber of the gizzard. They compare, not without reason, the air sacs of the bird with the branching lung of the Chamaeleon, but the chapter fixes our attention on account of the discovery of the nictitating membrane of the eye. This they had seen before, and it is mentioned casually here and there, but it was in the Cassowary that they were stimulated to disclose the complete facts. It is a remarkable piece of research, illustrated by simple workmanlike figures, and more detailed and trustworthy than many modern versions. They describe, in addition to the six normal muscles of the eye, the two muscles which draw the membrane over the cornea, and they show that the object of the movement is to keep the surface of the eye clean. The mechanics of the origin and doubling of the pyramidalis are understood and explained, and they realise that the quadratus does something more than withhold the tendon of the pyramidalis from the optic nerve. These are facts we have all at some time laboriously verified for ourselves, and we can therefore extend our sympathetic admiration to the men by whose genius and labour they were first laid bare; but the true merit of such a performance is rather the obligation it imposes on posterity of precise and exhaustive observation.

The chapter on the Indian Tortoise is an instructive display of the strength and weakness of the Parisians;

nor do they appear to have seriously respected the wishes of the King to return the specimen sufficiently intact for exhibition in the Museum. The origin and course of the cystic and hepatic ducts are worked out, the epididymes are unravelled, and their factors disclosed by the injection of a coloured fluid. The bladder is astutely recognised as comparable to the allantois of higher animals, and the urogenital organs receive masterly treatment. Even the comparative anatomy of the lung is only partially baffling, as we gather from their happy comparison of the chambered lung of the Tortoise with the almost parenchymatous lung of the Mammal. Vivisection itself is resorted to in matters of difficulty, and they were among the first to investigate the physiology of the lungs in a living animal in which respiration was maintained with a pair of bellows. The same experiment had been successfully demonstrated to the Royal Society by Robert Hooke four years before, but they go further than Hooke, and find that in the inflated lung an injection thrown into the pulmonary artery passes more readily through the capillaries into the pulmonary vein than in the deflated organ. To close the list of their successes, they discuss the nictitating membrane of the eye and its muscles, the relations of the tympanic cavity and the columella, and they realise that the extrusion of the head and the neck of the Tortoise is just as much a question of muscular *contraction* as its withdrawal—a simple deduction, but one which later biologists have not always comprehended. On the other hand, in spite of several ingenious—but misleading—experiments, they fail to grasp the broader facts of the Reptilian circulation. They confuse the hepatic veins with the postcaval, the aortic arches are regarded as branches of a single vessel, and, worst of all, they deny that the lungs exercise any effect on the blood, but are intended partly to compress the contents of the abdomen, and to act as hydrostatic organs like the swim bladder of fish. The circulation is compared with that of the Mammalian foetus, the blood passing from one side of the heart to the other, only a sufficient quantity being conveyed to the lungs to ensure the nourishment of those structures.

VIII

The influence of the Parisian School undoubtedly stereotyped for many years the character of anatomical research, and the completion of their work may well mark the close of the early struggles of comparative anatomy. Like the Insect emerging abruptly from the secret stresses of metamorphosis, our science, apparently by a single convulsion, moults the clogging accumulations of centuries, and assumes the activities of a free and independent existence. It would be unjust to claim, however, that the honours of the morphological renaissance belong solely to the founders of the French Academy of Science. They were themselves only an extreme and lively manifestation of the general revival of scientific learning, which was beginning to agitate the intellectual centres of Europe. We cannot forget that they had as contemporaries such men as Steno, Malpighi, Swammerdam, Willis and Thomas Bartholini, and whilst it must be admitted that they dominated the labours of their successors, of whom Muralt, Collins and Tyson may be quoted as examples, their contemporaries honourably staked out for themselves their own claim on the suffrage of posterity. It is with regret that we take leave of these sincere and venerable guides, and we may do so in the words of the greatest of all of them: "I avow myself the partizan of truth alone" . . . . . . that others, "starting from hence, and the way pointed out to them—advancing under the guidance of a happier genius, may make occasion to proceed more fortunately and to enquire more accurately."

REPORT ON THE INVESTIGATIONS CARRIED ON DURING 1912 IN CONNECTION WITH THE LANCASHIRE SEA-FISHERIES LABORATORY AT THE UNIVERSITY OF LIVERPOOL, AND THE SEA-FISH HATCHERY AT PIEL, NEAR BARROW.

EDITED BY

Professor W. A. HERDMAN, F.R.S.,
Honorary Director of the Scientific Work.

(With plates, charts and text figures.)

Contents.

INTRODUCTION.

This Report on the Scientific Fisheries work of the past year is drawn up on the usual lines, and is largely the work of the Scientific Assistants on the Staff.

The reports of Mr. Johnstone and Mr. Riddell nearly all deal with sections of our new scheme of fisheries investigation. 1912 has been the first (incomplete) year of scientific work with the help of a grant-in-aid from the Development Fund. When our last annual Report was issued, the intimation had just been received that the Treasury were recommended to place a sum of £1,640* at our disposal towards the expenses of the scheme of scientific work which had duly received the approval of the Board of Agriculture and Fisheries.

The Sub-Committee, which had been previously appointed to make, when the time came, any necessary changes in the posts and duties of the Scientific Staff and to fill up vacancies, met on April 26th for the allocation of the funds; and the new scheme of work started, with scarcely a day's delay, with the monthly cruise in the first week of May. This prompt utilisation of the funds placed at our disposal was only rendered possible by having all the necessary arrangements carefully planned beforehand, by having our Scientific Staff on the spot ready for work, and by the exercise of the utmost goodwill and friendly co-operation between all the bodies (Lancashire and Western Sea-Fisheries Committee, University of Liverpool, and Liverpool Marine Biology Committee) concerned in local Sea-Fisheries Investigations on the West Coast.

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* Of this amount only about £1,440 has been claimed for the financial year, 1912-13—the remainder of the expenses being defrayed from the funds of the Committee raised locally.

To meet various enquiries, I now place on record the following outline account of our scheme of work, with a summary of the results obtained so far. Further details on some points will be found in the full reports given below by the members of the Staff.

DETAILS OF THE SCIENTIFIC INVESTIGATIONS NOW BEING CARRIED ON WITH A VIEW TO THE DEVELOPMENT OF THE SEA-FISHERIES.

1. Hydrographic and Plankton Investigations.

Nature of Research.

Systematic observations of the temperature of the Sea off the coasts of Lancashire and North Wales, along with the collection of water samples for analysis, and of plankton samples throughout the year in the eastern half of the Irish Sea, the area not worked by the Irish Board, and extending to Holyhead, the Isle of Man and Mull of Galloway (see accompanying chart, p. 180).

Object.

To associate the temperature and salinity variations in the coastal waters with the movements and spawning periods of soles, plaice, flounders, whiting and cod.

By whom carried out.

The Staff on board the Fisheries steamer "James Fletcher" and the Hydrographic Assistant at the Liverpool Laboratory. The Naturalists at the Piel Laboratory and at the Liverpool Laboratory work out the plankton samples—both qualitatively and quantitatively.

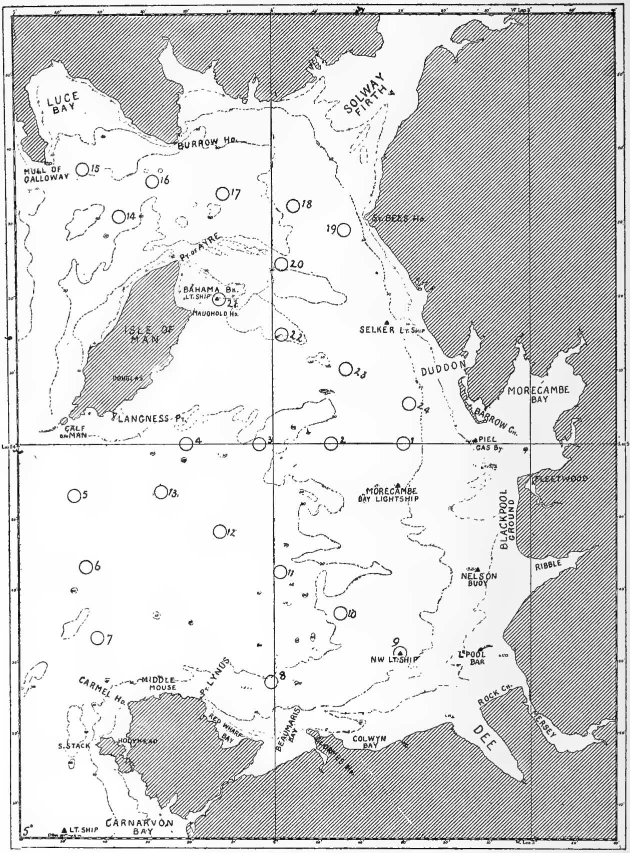
Methods.

Monthly cruises of four days each, involving whole time of steamer and crew. The rest of the work is carried out in the laboratories as part of the routine work.

2. Biological and Statistical Investigations.

Nature of Research.

Systematic collection of samples of plaice, soles and other fishes from various fishing grounds, at periodic times. The examination of these samples at the Liverpool Laboratory with respect to (1) size, (2) weight,



Observation Stations in 1912.

(3) age, (4) sex, (5) condition, (6) phase of reproductive organs.

Object. Deduction of the nature and amount of the migration from fishing ground to fishing ground, and between territorial and extra-territorial fishing grounds; estimation of the effect of the local Regulations with respect to trawl-meshes, &c.

Methods. *Fortnightly Samples* to be taken by the steamer from:—

Fishing grounds off the Ribble Estuary and along the coast to Liverpool Bay.

Fishing grounds in Red Wharf and Beaumaris Bays.

Monthly Samples:—

From fishing grounds in Cardigan Bay.

Fortnightly Samples taken by Bailiffs' sailing boats from:—

Fishing grounds in Barrow and Fleetwood Channels.

Fishing grounds in Mersey and Dee Estuaries.

Monthly Samples:—

From fishing grounds in Carnarvon Bay and Menai Straits.

Fishing grounds in Tremadoc Bay.

By whom carried out. Staff and crew of Steamer "James Fletcher," and of Bailiffs' sailing vessels;

Naturalist working on board the steamer;

Chief Bailiffs on sailing vessels;

Assistant Naturalist at the Liverpool Laboratory.

3. Fish-Marking Experiments.

Nature of Research. Investigation of migrations and growth of plaice and flounders by marking experiments.

Object. To determine the nature and amount of the migrations between fishing grounds and between intra- and extra-territorial waters. To trace the spawning migrations, and to estimate the rate of growth of these fishes.

By whom carried out. Crew of Steamer "James Fletcher"; Naturalist on board steamer; and Naturalist at Liverpool Laboratory.

Methods. Involves the marking of at least—

- 200 plaice in Morecambe Bay in March-April.
- 400 plaice in Nelson Buoy Fishing Area (Ribble estuary)—June-July.
- 200 plaice in Mersey and Dee Area—July-September.
- 400 plaice in Beaumaris and Red Wharf Bays—November-January.
- 200 flounders in Morecambe Bay.

The examination of the marked fish returned to the Liverpool Laboratory.

4. Routine Trawling Experiments.

Object. Systematic trawling observations with the object of determining abundance and distribution of edible fishes in general on the fishing grounds not specifically mentioned under headings 2 and 3, and on those fishing grounds at periods intermediate to those on which the observations and experiments under 2 and 3 are being made.

By whom carried out. Steamer "James Fletcher," and Bailiffs' sailing vessels; Naturalist on board steamer; and Naturalist at the Liverpool Laboratory.

Methods. Trawling experiments by vessels mentioned above, the collection of material by Naturalist on board steamer for further examination at the Liverpool Laboratory.

Further Remarks on the above Scheme.

I. Hydrographic and Plankton Investigations.

These investigations were commenced in 1906. There were then three lines of Stations:—(1) Piel Gas Buoy to Calf of Man (parallel of latitude 54° 00″); (2) Calf of Man to Holyhead; (3) across the mouths of Carnarvon and Cardigan Bays; ten Stations in all.

These Stations were visited regularly (at three-monthly intervals) during the years 1907 and 1908.

In 1909 one line of Stations (3) was discontinued; while two new lines were then added: (4) Liverpool North-West Light-vessel to Calf of Man, four Stations; and (5) Piel Gas Buoy to Maughold Head (Isle of Man), three Stations.

Lines 1 and 2 were investigated monthly (except in December) during 1909, and Lines 1 to 5 were investigated quarterly.

In 1910 the Lines 4 and 5 were discontinued pending the receipt of support from the Treasury, and only quarterly cruises were carried out.

In 1911 it was found necessary to discontinue the May and August quarterly cruises.

In 1912 the Stations on Lines 1 and 2 were investigated in February, and in May Lines 4 and 5 were re-instated. Three new Lines were added:—(6) St. Bees Head (in Cumberland) to Bahama Light-vessel (Isle of Man), (7) Point of Ayre (Isle of Man) to Mull of Galloway (Scotland), and (8) Mull of Galloway to St. Bees Head—bringing the total number of Stations up to 24. These are the Stations included in the present scheme of investigations as laid before the Development Commissioners, and approved by the Board of Agriculture and Fisheries (see Chart, p. 180).

Lines 1 and 2 are investigated monthly, and Lines 1, 2, 4, 5, 6, 7, 8 are investigated quarterly. Hydrographic soundings are made on Line 2 only. At the other Stations only surface samples are collected, and only surface observations made.

In addition to these periodic investigations, surface sea-temperature observations are made from the S.S. "James Fletcher" hourly when the vessel is at sea. These observations are altogether very numerous, but the area under investigation is large, so that at some points the number of observations is not relatively great. Further, the vessel, when not on a hydrographic cruise, is necessarily obliged for the most part to cruise along certain definite tracks, and sea-areas in which illegal trawling may occur are more often visited than are other areas. The result is that our detailed knowledge of the temperature of the sea on some of the important fishing grounds throughout the year is still far from complete.

The water samples are examined chemically by Prof. H. Bassett, and the salinities are determined by him. These results for the past year, and a discussion with reference to the water circulation in the Irish Sea, and the weather conditions of 1912, are contained in Dr. Bassett's report, which is printed below.

The statistics of the winter plaice fishery off the coasts of North Wales have been analysed by Mr. James Johnstone, and an attempt has been made to deduce some relationship between the variations in this fishery and the deviations from normal conditions of the sea with regard to temperature. So far, however, no clear and certain relationship between these events can be demonstrated.

It is certain, nevertheless, from our observations, that there are considerable differences of temperature in the sea along the coasts of Lancashire and Wales, and that the rate of heating and cooling at different places is not the same from year to year. Neither are the minimum and maximum temperatures the same from year to year, nor are the dates of the minima and maxima always the same.

The fishery statistics again show distinct differences from year to year (1) with respect to the quantity of fish caught per day's fishing, and (2) with respect to the dates of maximum catches. But no definite relation between these two kinds of variation (temperature and fishery statistics) can yet be established. Possibly, however, the existing data, when they have been accumulated for a much longer time, will enable us to show some such relationship. All the data on which conclusions might be based are kept and published.

II. Fish Measurements and Examinations.

During the year 1912, 30 samples of plaice have been examined in the Liverpool Laboratory. The examination includes (1) length measurements, (2) weights, (3) sex and age determinations.

Altogether 127 samples, including 10,672 plaice, have now been examined.

The series of samples are satisfactory with regard to two fisheries: (1) the summer plaice fishery off the coast of North Lancashire, and (2) the winter plaice fishery off the coast of North Wales. These samples were collected by the S.S. "James Fletcher."

The samples received from the other parts of the district are as yet too few to be of much use, and we think it best to draw no conclusions from them.

All the plaice caught by the S.S. "James Fletcher" in the course of the usual trawling experiments have been measured. Here again the data with respect to the two fisheries mentioned above are of value. An interesting series of measurements of plaice caught in a shrimp-trawl net have also been made by the officer in charge of the New Brighton Fishery Station. All these figures are tabulated in the report which is being prepared. They will be useful for future discussions, but no useful purpose would be served in considering them now.

III. Fish-marking Experiments.

Owing to the pressure of other work, only one of the proposed experiments was made. About 400 plaice were marked and liberated at Nelson Buoy, off the mouth of the Ribble Estuary. The recaptures are tabulated in the report, but, so far, it would be premature to discuss the results.

In addition to the work carried out under the above-described scheme, we have also several other investigations to record.

A number of interesting pathological specimens have been received during the year, chiefly from the Port Sanitary Inspector at Fleetwood. These have been examined by Mr. Johnstone, who reports upon several diseased conditions of fish. Dr. Moore Alexander continues his bacteriological investigations by reporting on a case of true piscine tuberculosis.

I have set Mr. H. G. Jackson, who is carrying on Fisheries research work in the Zoological Department of the University, to examine all the higher Crustacean larvae obtained in our various plankton gatherings, and to trace these young stages of crabs and lobsters, shrimps and prawns, and other allied animals, throughout their life-histories, and also in their distribution over the district and through the year. A first report on this subject from Mr. Jackson appears now, and a more detailed account of the matter will be ready next year.

Mr. Robert Ray, a post-graduate research worker in the Zoological Department, has given valued assistance by undertaking some of the work at sea on the periodic cruises, and he has also started a comprehensive investigation of the bottom deposits of the various fishing grounds in the Irish Sea, especially in their relation to the animals, large and small, associated with particular kinds of deposits, and to the food, direct or indirect, of edible fishes. This research ought to throw light on the biological significance of the various deposits and their influence on the distribution of demersal fishes. The work, though in progress, is not yet sufficiently advanced to justify publication, but Mr. Ray will probably have a report ready for next year's volume.

The plankton work published in this report is in continuation of that given in last year's volume, and in addition to the " Intensive Study " in the Irish Sea, and the observations on the sea outside our area to the north, Mr. Riddell gives a first report on the plankton of the periodic cruises in the S.S. " James Fletcher."

Mr. Scott's report on the Fish Hatching at Piel shows that in the case of the Flounder the operations resulted in the liberation of 13 millions of fry, and in the case of the Plaice of one million fry, which must be regarded as satisfactory, considering the limited space.

A considerable portion of our travelling Fisheries Exhibition has, at the request of the Board of Agriculture and Fisheries, been sent to the International Exhibition to be opened at Ghent next month.

Following on the historical survey on the origin and progress of public-health bacteriology in the Lancashire Sea-Fisheries district which I gave last year, we have now a detailed report by Mr. Johnstone on the more important mussel beds of Lancashire and North Wales as regards their liability to sewage contamination. Most of these mussel beds have been re-surveyed during 1912, and the present full report demonstrates again what we have urged in the past, that further supervision, regulation and development of our shell-fish beds is urgently required in the interests both of the public health and of the threatened fishing industry. The necessity for more searching and critical methods of bacteriological analysis is also clearly shown.

Thus there is now a great opportunity offered for an experiment on an industrial scale, either at Conway or elsewhere, to show the beneficial effects of a few days' transference of all polluted shell-fish to cleansing tanks before exposure for sale as human food. This is probably one of the finest possibilities that has ever presented itself of applying the results of scientific investigation to the improvement and development of a deserving fisheries industry, and it will be most unfortunate if the Authorities concerned fail to make use of the opportunity now open to them.

W. A. HERDMAN.

FISHERIES LABORATORY,
UNIVERSITY OF LIVERPOOL:
March 26*th*, 1913.

FISH HATCHING AT PIEL.

By Andrew Scott, A.L.S.

The fish hatching conducted in the spring of 1912 produced results almost similar to those of previous years. The adult plaice were collected in Luce Bay, by the kind permission of the Fishery Board for Scotland, early in September, 1911. The temperature of the air and sea was unusually high at the time of our visit to the bay, and for some days after the fish had been landed at Piel and placed in the tanks. We had, therefore, considerable difficulty in keeping them alive. It was only by maintaining a greater flow of water through the tanks than would have been required under ordinary circumstances that the fish remained healthy, and very few deaths occurred. The fixing of the date of the visit to Luce Bay as early as the beginning of September in 1911 was chiefly due to the rough weather which had been so frequently experienced in previous years on the passage back to Piel with the fish. A later date has given us less trouble, even although the weather be somewhat unsettled. The knowledge acquired for regulating the flow of water through the tanks while the fish are on board, and the careful management of the steamer by Captain Wignall to avoid unnecessary disturbance of the fish, enable us to carry them to Piel in comparative safety. The flounders were obtained from the channel in the vicinity of Piel by the police cutter stationed in the northern division of the district.

The first fertilised flounder eggs were secured on

March 14th. The plaice commenced to spawn three days later. During the last dozen years the date on which fertilised eggs were first obtained from flounders in the tanks has varied from February 28th to March 14th. Only once before, in 1906, has the spawning of the flounders been so late, and that was also on March 14th of that year. The spawning of the plaice kept in the tanks has varied from March 4th to March 21st. The spawning of the fish in 1912 lasted for nearly seven weeks. During that time, one million two hundred thousand plaice eggs were obtained, and thirteen million seven hundred thousand flounder eggs. The eggs were incubated in the usual way in the Dannevig hatching apparatus, and the resulting fry were afterwards liberated in the sea. The incubation of the plaice eggs varied from sixteen days during March to fourteen days in April. The flounders required eleven days to incubate in March and seven days in April. At the end of the spawning time, when the adult plaice were finished with, a few of them were marked by Mr. Johnstone and liberated outside Walney by Captain J. Wright, when he was taking the fishermen across to Fleetwood after the completion of one of the classes. The remainder of the adult fish were set free in the channel off Piel.

The following tables give the number of eggs collected, and of the fry hatched and set free on the dates specified :—

PLAICE (*Pleuronectes platessa*, Linn.).

		Eggs Collected.	Fry Set Free.		
March	16	30,000	25,500	April	9
,,	18	45,000	39,500	,,	,,
,,	21	60,000	51,000	,,	17
,,	23	75,000	65,500	,,	,,
,,	25	75,000	65,500	,,	,,
,,	28	85,000	74,000	,,	22
,,	30	90,000	79,000	,,	,,
April	2	95,000	84,000	,,	25
,,	4	95,000	84,000	,,	,,
,,	6	90,000	79,000	,,	30
,,	9	85,000	74,000	,,	,,
,,	12	80,000	69,000	May	4
,,	16	70,000	60,000	,,	,,
,,	19	65,000	57,500	,,	11
,,	22	55,000	46,000	,,	,,
,,	24	45,000	40,000	,,	14
,,	27	35,000	30,000	,,	,,
,,	30	25,000	20,000	,,	18
Total Eggs		1,200,000	1,043,500	Total Fry.	

FLOUNDER (*Pleuronectes flesus*, Linn.).

		Eggs Collected.	Fry Set Free.		
March	14	250,000	220,000	April	2
,,	16	400,000	355,000	,,	,,
,,	18	550,000	475,000	,,	8
,,	21	700,000	600,000	,,	,,
,,	23	800,000	710,000	,,	12
,,	25	800,000	710,000	,,	,,
,,	28	900,000	800,000	,,	17
,,	30	950,000	845,000	,,	,,
April	2	1,100,000	975,000	,,	22
,,	4	1,100,000	975,000	,,	,,
,,	6	1,000,000	887,000	,,	25
,,	9	900,000	800,000	,,	,,
,,	12	850,000	757,000	,,	30
,,	16	800,000	710,000	,,	,,
,,	19	800,000	710,000	May	4
,,	22	750,000	660,000	,,	,,
,,	24	500,000	436,000	,,	11
,,	27	350,000	300,000	,,	,,
,,	30	200,000	175,000	,,	14
Total Eggs		13,700,000	12,100,000	Total Fry.	

Total Number of Eggs	14,900,000
Total Number of Fry	13,143,500

CLASSES, VISITORS, &c., AT PIEL.

By Andrew Scott.

The usual four classes for fishermen were held at Piel in the spring of 1912. The Education Committee of the Lancashire County Council voted the necessary sum of money which allows forty-five fishermen residing in the Administrative Area to come to the establishment and receive a course of instruction in Elementary Marine Biology. They also permitted their County Navigation Instructor to attend for a period of six weeks. He gave instruction in Seamanship and Navigation to the men from the Administrative Area who were qualified to sit for the Board of Trade certificates. The Southport Education Committee sent four men, and the Blackpool Education Committee again sent three men. There were no fishermen students from Cheshire, Liverpool or Cumberland in 1912. A total of fifty-two fishermen attended the classes and received instruction in Marine Biology. Thirty-nine of them also attended the course in Navigation. The men selected to attend were divided into four classes—one of fourteen, two of thirteen each, and one of twelve, as shown by the following lists:—

First Class, held March 11th to 22nd.—Harry Cowperthwaite, Flookburgh; James Hill, Flookburgh; Richard Curwen, Snatchems, near Lancaster; Edward Woodhouse, Morecambe; C. D. Brook, Blackpool; T. Hayes, Blackpool; W. Owen, Blackpool; James Johnson, Banks; Thomas Abram (Edwards), Banks; William Wright, Marshside; Robert Ball, Marshside; Richard Sutton, Marshside; John Rigby, Southport.

Second Class, held April 9th to 19th.—H. Curwen, C. A. Darnell, W. Dewhurst, T. Newby, Henry

Ormond, James Sandham, H. J. Snasdell, A. Sucker, J. Tomlinson, Harry Wright, Richard Wright (*a*), Richard Wright (*b*), Fleetwood.

Third Class, held April 22nd to May 3rd.—J. Ainsworth, J. W. Bedson, John Brunton, J. W. Cooke, Thomas Dewhurst, Martin Fielding, George Meikle, Fred. Leadbetter, James Owers, S. Philips, A. W. Pilkington, Robert Swales, E. Wood, W. Welsh, Fleetwood.

Fourth Class, held May 6th to 17th.—W. R. Birnie, F. Brunton, G. Cass, J. Christian, W. C. Claydon, W. Hayes, J. Leadbetter, J. W. Matthews, Paul Pettersen, John Scott, J. Smith, J. Rimmer, H. B. Wright, Fleetwood.

The first class was attended by cocklers, musselers, shrimpers and men from second-class fishing boats. The course of instruction dealt with general Marine Biology, and was similar to what has been given in former years. The second, third and fourth classes were only open to deep sea fishermen residing in Fleetwood. The selected men had put in the necessary sea time to qualify them to sit for the Board of Trade examinations for certificates as second hand or skipper of a fishing vessel. The morning lesson, lasting two and a half hours, was devoted to instruction in Marine Zoology having a more or less direct bearing on the habits and life-histories of the fish and more common invertebrates captured in the trawl net. The afternoon lesson of three hours was conducted by Captain E. Barker Thornber, the County Navigation Instructor. A very efficient course in Navigation and Seamanship was given. An interesting acknowledgment of the success of these navigation courses and the teaching work of Captain Thornber was received by telegram during one of the afternoon meetings of the third class from three of the students who had attended the second class. The telegram contained the pleasing information that they had passed the Board of Trade examination and obtained their skipper's certificate. One of them was shortly afterwards appointed master of a steam trawler.

The annual inspection of the classes was made by Mr. Hopkinson, Chairman of the Finance Committee, and a party of Members of the Bury Corporation on May 16th. A short address describing the administrative and scientific work carried on by the Committee was given in the Laboratory to the visitors by Mr. Hopkinson, who acted as leader in the absence of the Chairman of the Sea Fisheries Joint Committee. They then inspected the work being done by the fishermen students, and afterwards a few complimentary speeches were made.

Mr. A. Harris, H.M. Inspector of Evening Schools for the district, paid an official visit, and inspected the teaching work that was going on. Professor Herdman and Dr. Jenkins also visited the establishment during the year. The usual visits by members of local rambling clubs and others interested in scientific work were made on the Saturday afternoons during March, April and May.

Our thanks are again due to the United States Fisheries Department; the Smithsonian Institution; Professor E. Ehrenbaum, of the Biological Station at Helgoland; Dr. Annandale, Superintendent of the Indian Museum; Mr. E. W. L. Holt, the Scientific Adviser to the Irish Fisheries Department; and others, for additions to the Library. The whole of the unbound volumes, pamphlets, &c., have recently been bound with serviceable covers, and are now in better condition for reference.

DISEASED CONDITIONS OF FISHES.

(Plates I-III.)

By Jas. Johnstone.

Contents

Tubercular lesions in a Cod (*Gadus callarias*).

A fairly large cod landed at Fleetwood in March, 1912, exhibited this condition. Part of the fish was sent to me by Mr. T. R. Bailey, Port Sanitary Inspector. The piece sent, all that behind the origin of the second dorsal fin, showed that it was a spawning male in apparently good condition. There were some copepod parasites, *Anchorella uncinata*, on the vertical fins, and the flesh seemed to be healthy and unaffected.

There were numerous lesions on the skin, the tail and the dorsal and ventral fins. These took the form of little rounded, slightly raised, pigmented nodules in the integument. They were hard to the touch, particularly on the fins. As a rule, they occurred singly, when they were about 5 mm. in diameter, and were raised above the general surface of the integument about ½ to 1 mm. The pigment was sometimes reddish-black when the fish was fresh, sometimes grey-black. After preservation in formalin the reddish pigment disappeared and all the nodules became black, particularly at their margins. The central parts were sometimes creamy-yellow in colour, with some very fine pigment spots (see fig. 2, Pl. III).

Although these nodules occurred singly for the most part, there were patches of skin where they were grouped, and here the lesion was a distinctly ramifying one, sometimes even dendritic in appearance. This was more particularly the case on one side of the fish, and on both sides between the beginning of the third dorsal fin and the root of the tail fin. In some places quite considerable areas of skin were involved. Over the nodular lesions the epidermis had quite disappeared and there were no traces of scales, but elsewhere the skin was apparently normal in structure. On slicing away the surface of these little nodular masses a cheesy-white substance was disclosed, and sometimes this could be apparently "shelled-out," when it appeared as little granular masses of various shapes and sizes. Some of these were stained and cleared up, but they showed no obvious indications of structure.

In my absence from the laboratory the fish was preserved in formalin. It was first of all examined, as above described, for the possible presence of worm parasites, but nothing of the kind was found. Rough smears were then made from the substance in the nodules, to see if fungoid or protozoan organisms were present, but again with negative results. Sections through the nodules were then made, and were stained in various ways, methyl-blue-eosin, iron-haematoxylin followed by eosin, Ehrlich's haematoxylin and eosin, and Mallory's stain. On examining the sections so prepared it was at once seen that morbid tissue formation had taken place, and what was seen indicated the presence of an infectious granuloma of some kind. Prof. Glynn, of the Pathological Department, to whom I showed the sections and specimens, at once noticed their resemblance to tuberculous lesions, and suggested staining for acid-fast bacilli. This was done,* and the nature of the lesions then became apparent. They were evidently tubercular, and the whole was a spreading infection of the integument forming lesions, most of which were in the process of healing.

Fig. 1, Pl. II, represents a section through one of the smaller nodules which had been stained with methyl-blue-eosin. It includes a part of the normal integument on the right-hand side, where a scale is shown cut in section. The epidermis has disappeared everywhere, but the loose areolar connective tissue lying beneath it is shown. Beneath the scale is a thick layer of coarse connective tissue fibres, and beneath this again loose areolar tissue; none of the underlying systemic muscles are shown.

It will be seen that the lesion involves only the integument, and that it is the thick layer of coarse connective tissue fibres that has been affected. Under the surface of the nodule this has almost entirely disappeared, though in the sections which have been Mallory-stained little groups of these fibres or isolated fibres can be seen, owing to their peculiar staining reaction. The characteristic structures displayed by the sections are, however, the parts which are darkly stippled in the drawing. These stain deeply with

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* Staining reactions. Sections fixed on the slide were stained for five minutes in the Ziehl-carbol-basic-fuchsin liquid, the latter being hot: some were also stained in the cold for 24 hours. They were decolourised with 20 % sulphuric acid for at least ten minutes, when the stain remained in the bacilli. Sections were stained in the hot liquid for ten minutes, and in the cold liquid for 24 hours, and then placed in 25 % sulphuric acid for 24 hours, washed, cleared and mounted in balsam: in these also the bacilli retained the stain. In these latter preparations the beaded appearance of the bacilli was not evident. Smears made from the substance of the nodules were stained and decolourised as above, but the bacilli could not always be seen. Sections were stained in carbol-thionin for a few minutes and then treated with Gram solution in the usual way: the bacilli did not retain the stain. Smears and sections were stained in carbol-gentian-violet and in thionin in the cold for a few minutes: the bacilli did not stain.

methyl-blue-eosin, and it is here also that the bacilli are massed together. Some of these darkly-staining parts appear to lie inside small cavities, which are bounded by fine fibrous tissue arranged concentrically, and it is these large masses which appear to shell-out when the superficial part of the nodule is cut away. It is very probable that the cavity shown in the figure is an artificial one, that is, it is produced by the action of the preservative. But in many of the smaller nodular masses there are also indications of the formation of this concentric fibrous tissue, though there may be no space between the bacilli-loaded centres and the fibrous investment. What we see here is doubtless the encapsulation of the tuberculous centres. But there are also many darkly-staining parts of the section evidently densely packed with organisms, and round these there are no traces of capsules: the darkly-staining tissue passes without any discontinuity into the ground tissue of the section.

Fig. 3, Pl. II, represents a small part of one of these smaller tubercular centres as seen under an oil-immersion lens. It will be seen that there are distinct traces of a capsule, in that fibrous tissue is arranged concentrically round the mass. This rather loose capsular tissue, and some relatively coarse fibres, with large and small connective tissue nuclei, are all the histological elements which can easily be recognised. Besides these there are some rather large patches, staining deeply and without much differentiation with methyl-blue-eosin; and in these are some rounded bodies, staining blue, and containing numerous granules, but no evident nuclei. These present a certain resemblance to the "giant-cells" of typical tuberculous lesions, though, of course, it would be hazardous so to identify them.

In the Mallory preparations most of these obscure bodies stain orange, just as do the nuclei of the red blood corpuscles in other parts of the section where capillaries are present and can be recognised, and in the sections stained with carbol-fuchsin these parts take the stain very intensely. They, therefore, consist mainly of broken-down red blood corpuscles, connective tissue fragments, and masses of bacilli densely aggregated together.

The remainder of the substance of the lesion between the nodular masses consists of fibrous connective tissue with blood capillaries. It is not richly vascular, but the capillaries with their contents can easily be recognised. It is a granulomatous, or scar, tissue, and doubtless represents the tubercular lesion in process of disintegration and absorption. It contains pigment-melanin granules without much indication of arrangement. Here and there this pigment appears in a stellate form, as if it were contained in richly branching cells, but as a rule it is present as small round bodies or discrete granules.

All the darkly shaded parts in fig. 1, and especially the darkly stippled parts, are the *loci* of the bacilli staining acid-fast with carbol-fuchsin. The deeply stippled areas represent places where the bacilli are densely clumped. These clumps are spherical masses of various sizes in which the organisms lie densely packed together without any definite arrangement. Outside them the organisms lie loose in the tissues, and never arranged in chains. They have the form regarded as typical of the tubercle bacillus, that is, they are relatively long, slender, slightly curved rods, and for the most part they present a richly-beaded appearance, due to the vacuolation of their cell bodies. Round all these clumped masses of organisms there is a diffuse pink staining, as if some substance had been excreted by the bacilli into the surrounding tissues, and this had taken the stain in the same way as the organisms themselves.

The lesion is then obviously the result of an infective disorder, and the general similarity of structure of the nodules with those produced in warm-blooded animals by the tubercle bacillus justifies us, I think, in describing it as a case of piscine tuberculosis. The pigmentation of the skin is a frequent feature in lesions of many kinds in fishes: it is to be associated with inflammatory processes, and has no particular significance. Piscine tubercle is of course known,* but, so far as I can find, only from fresh-water species, and it is of interest to find so typical a condition in a fish living in the open, and not at all likely to have become infected by land drainage.

The detailed bacteriology of these lesions is described by Dr. Alexander on page 219.

Ovarian Cysts in Angler (*Lophius piscatorius*).

A female Angler, about 5 feet in length, was sent to the Laboratory last May by Captain Wignall. On dissecting it with a view to the discovery of worm parasites, it was noticed that the wall of the ovaries contained rounded cyst-like bodies. The fish was a spent one: the ovaries were quite empty, and their wall was represented by a germinal epithelium containing practically only one layer of very small ova. The cysts were usually attached to the external surface of this: they were of various sizes, the largest being about 2½ by 1½ cms. in diameter, and the smallest being about ¼ cm. Their shapes varied, some being almost spherical,

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* See Hofer, *Handbuch der Fischkrankheiten.* Stuttgart, 1906.

other ellipsoidal, other again quite irregular and constricted, as if they were made up of several smaller cysts coalescing together. In one case a group of four were attached together, and were suspended from the ovary by a single pedicel.

The wall of these bodies was, as a rule, thin and almost transparent, but in some cases the cyst was constricted about its middle, and one-half of the whole structure would possess a thin clear wall, while the wall of the other half would be thick and opaque. On preservation in formalin the whole structure swelled slightly and its walls became tense, doubtless by endosmosis. On opening the cyst an albuminous fluid exuded, but after preservation it was sometimes possible to open the cyst and "shell-out" the contents as a clear semi-solid mass. As a rule, this showed no structure when looked at under the microscope, except a kind of froth appearance, due doubtless to incipient coagulation of the contents.

Fig. 1, Pl. III, is a photograph of several of these bodies, nearly natural size. One compound cyst is shown, and several smaller ones. Some of the cysts showing a dense wall are also photographed, and a piece of germinal epithelium, showing a cyst on the internal surface, is also represented.

At first sight these structures appeared to resemble cysticercoids; but no traces of a scolex could be seen on dissection, nor any trace of calcareous corpuscles, when the thin wall was examined microscopically without preparation. Sections were then made, and it was seen that they were mucoid cysts, somewhat similar to the bodies described in pathological works as ovarian cysts.

Fig. 5, Pl. I, represents a section through the wall of one of the translucent cysts. It is thin, about

0·06 mm. thick, and consists of several fairly well marked layers. Next the external surface is a thin layer of dense connective tissue fibres, and then a layer of rather loose areolar tissue containing round cells. Next the internal surface is an epithelium consisting for the most part of rounded cells, in places suggesting a cubical epithelium. For the most part it is broken down, but here and there are indications of the presence of mucous cells. Two such are shown in the figure containing large "goblets." This layer doubtless represents the remains of an epithelium which has secreted the mucus filling the cyst, and has been almost entirely disintegrated by the shedding of its products. Between these two layers is a broad one consisting of connective tissue fibres running round the cyst. Some of these are straight, but the majority are greatly twisted.

Fig. 6, Pl. I, represents part of a section through one of the cysts possessing a thick opaque wall. The structure is obviously entirely different from that of the thin-walled cysts. The most prominent element in it is the mucous epithelium lining the interior—this is thrown into folds and prominences resembling the villi of a mammalian intestine. Part of one of these folds is represented in fig. 7 as seen under an oil-immersion lens, and fig. 8 represents a villus cut near its tip in transverse section. The epithelium is a columnar one, as is seen on the right in fig. 7. As a general rule, little of the layer exists in this condition, but here and there are relatively large patches of the unmodified columnar cells. For the most part, however, the appearance is that suggested by fig. 7, that is a "goblet-cell" epithelium. The "goblets" are about 0·04 high, and are quite typical in structure: one of them is shown in fig. 7 with the section passing through its aperture.

The columnar cells are high and slender, and have their nuclei at the extremities away from the cavity of the cyst. Their free extremities are banded: a densely staining zone forms the free edge of the cell, and then next to this is a lightly staining zone.

The external layer of the wall resembles that of the thin-walled cysts already described, and next to this is a layer composed mostly of smooth connective tissue fibres. In this, however, there are numbers of unstriated muscle fibres, all running in one direction. Between this and the layer of columnar epithelium is a layer consisting mainly of loose areolar tissue. Elastic fibres, however, pass from the denser layer through this into the interior of the villus-like structures. There are some rather remarkable glandular bodies in this areolar layer: these are represented by the darkly stippled patches in fig. 6, and they are also shown in fig. 11 as seen under an immersion lens. They consist of groups of cells, sometimes arranged irregularly, but as a rule grouped round a small but most distinct lumen or cavity. The cells are rather of the "eosinophilous" type, finely granular in structure, and with small darkly staining nuclei near their outer extremities. These glandular bodies do not seem to be connected together, nor do they open into the cavity of the cyst.

Blood vessels are very few in either the thick- or thin-walled cysts, but there are cavities in the thin-walled bodies which are filled with small lymphocytes.

The cysts do not, then, appear to resemble any structures figured in pathological works. Yet they are undoubted morbid growths.

A Phycomycetous Fungus in a Mackerel (*Scomber scomber*).

A mackerel caught by Mr. A. Scott off Walney Island in July last, proves to have been infected by a fungus. It was at once apparent on opening the fish that the viscera were in a morbid condition. The liver was hard to the touch and granular in appearance, the whole surface being marked by slight rounded elevations from $\frac{1}{4}$ to 1 mm. in diameter. The substance of the organ was friable and easily broken down. The kidneys presented a somewhat similar appearance, and the spleen was also affected. The fish was a spent female, and on slitting open the ovaries minute opaque bodies were seen on the folds of germinal epithelium. The peritoneum covering the pyloric caeca, particularly where it connected these tubules, contained great numbers of small opaque spherical bodies, varying in diameter from 0·32 to 0·05 mm. On dissecting these away they were seen to be attached together by delicate strands of peritoneal tissue. Cleared in clove oil they were seen to contain small round, granular masses about 0·04 to 0·06 mm. in diameter, each surrounded by a very distinct structureless capsule, while round that again was a fibrous capsule of variable thickness. The larger bodies usually contained several (from two to eight) of these spherical structures, each with its own capsule, while the aggregate was also enclosed in a capsule; exceptionally a much larger number was contained in the same compound capsule, but the usual number was small. A group of these bodies is represented in fig. 4, Pl. II.

Sections were made from parts of liver, renal organ and ovary. The infection is very intense in the liver, so much so that about three-fourths of the hepatic tissue has disappeared. Three main kinds of foreign bodies are to be seen. (1) Structures like that shown in fig. 1, Pl. I, possessing a very distinct fibrous capsule, and varying greatly in size. The larger ones are essentially similar to that represented in the figure, but in the smaller ones the capsule is much less distinct. (2) Groups of bodies like those represented in fig. 4, Pl. I. Some of these are capsulated, but in others there is no distinct boundary between them and the surrounding liver tissue. (3) Other bodies similar to the larger ones shown in fig. 4, Pl. I, each enclosed in a very distinct capsule, with an outer investment of fibrous tissue. Between all these foreign bodies is the hepatic tissue, perfectly normal and well preserved in spite of the formalin fixation.

The infection of the ovaries is relatively slight. In these organs the germinal epithelium is thrown into deep longitudinal folds projecting into the cavity of the organ. The epithelium itself is very thin and the ova are on its internal surface—within the folds. Among the ova, sometimes apparently attached to the epithelium, but in other cases lying quite loosely, are foreign bodies essentially similar to that shown in fig. 1, Pl. I. They are, however, few in number, but still abundant enough to show up clearly when the organ was examined by means of a hand-lens.

Fig. 1, Pl. I, represents a part of a section of the renal organ. For the most part the foreign bodies in this organ are of the type figured here. A fairly thick fibrous capsule surrounds a mass of tissue containing very numerous small nuclei. In the centre of this there is usually a thick, densely staining, structureless capsule, which is sometimes crumpled or collapsed, and usually empty. Sometimes, however, this capsule contains a round body like those shown in fig. 4. As a rule the nuclei are imbedded in a granular mass of no very definite structure, but sometimes they appear to be the nuclei of small cells lying fairly distinctly from each other. In most cases the intrusive bodies in the renal organ consist of this strong fibrous capsule, an ill-defined layer representing the nucleated tissue of fig. 1 and the central capsule. In many cases the body within the central capsule has burst the latter and has begun to exhibit vegetative reproduction. In figs. 2 and 3, Pl. I, such a case is represented—doubtless the beginning of formation of a mycelium.

The tissues of the renal organ apart from these bodies are quite normal. Several excretory tubules are represented in fig. 1 surrounded by small lymphocytes—all this is perfectly normal, and the fixation of the tissue is quite satisfactory.

In a number of places both in the liver and renal organ, "nests" of bodies exist, lying almost loosely in the general renal or hepatic tissue. Such a "nest" is shown in fig. 4, Pl. I. It contains a number of small spherical bodies, each surrounded by a rather delicate, structureless capsule, and the whole lies quite loosely among the liver parenchyma. In some cases these capsules burst, and the contained body appears to be proliferating or budding. This is shown in fig. 2, in its first stage. In fig. 4 there is undoubtedly the beginning of a mycelium, and this is still more clearly shown in fig. 3, which represents part of a section of the renal organ. We have clearly a case of the infection of the fish by a fungus, and the growth of the latter within the organs.

Dr. H. M. Woodcock, to whom I showed these sections, has drawn my attention to a paper by Plehn and Mulsow,* in which the causes of the disease called "Taumelkrankheit," by Hofer, are investigated. This is a disease attacking fresh-water fishes, chiefly trout,

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* Plehn and Mulsow, "Der Erreger der 'Taumelkrankheit' der Salmoniden." *Centralbl. f. Bakt.* LIX Bd., 1911, Originale, pp. 63-68, 1 pl.

and characterised by lack of co-ordination in the swimming movements of the animal. It lasts for some weeks and usually leads to the death of the fish. Hofer found* that various organs in the animal were infected by an organism which he regarded, provisionally, as a sporozoan. They were contained in rounded or oval cysts, many of which showed proliferation, or vegetative growth. Plehn and Mulsow were successful in isolating these bodies and cultivating them in artificial media, when a typical mycelial growth was produced. The appearance of this is represented in their figures. They were able to show that it was a Phycomycete fungus belonging to the group Chytridinae, and they called it *Ichthyophonus Hoferi.* Now I think there can be no doubt that the parasite here described from the mackerel is very closely allied to the species of Plehn and Mulsow, if it is not identical, but in the absence of fresh material capable of setting up cultures it is, of course, impossible to be certain, and I hesitate to make the identification.

A closely similar condition was described by me in 1905.† Plaice living in captivity in the spawning pond at Port Erin Fish Hatchery became subject to an epidemic disease, characterised by extensive ulceration and death of the fish. Some of these fish examined by me proved to be infected by a fungus which I identified as a genus of Entomophthorineae, near to the form *Conidiobolus.* The appearance of the organism in these plaice was rather different from that written about here. A mycelium was established in the liver, and this growth was much more massive than that found in Mr. Scott's mackerel. I attributed the disease and death of these

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* Hofer, Handbuch der Fischkrankheiten. Stuttgart, 1906, pp. 286-289, Text-figs. 177-181.

† Johnstone, "Internal parasites and diseased conditions of fishes." *Ann. Rept. Lancashire Sea Fisheries Laboratory* for 1905. In *Trans. Liverpool Biol. Soc*, Vol. XX, 1906, pp. 295-329, Pl. XVI., figs. 3-7.

plaice to the effects of this fungus, but later cases of epidemic disease occurred at Port Erin, and the fish that died had all the appearance of those studied by me in 1905. An epidemic of this kind was studied by Riddell and Alexander in 1911.* Extensive ulceration of the fish was found, and an invasion of the body by certain bacteria. There were, however, no traces of a fungus in any of the internal organs. It is therefore likely that the fungus invasion and the ulcerative condition of the fishes studied by me were concomitant conditions; as in the case of the *Saprolegnia* disease among salmon. The ulceration and consequent weakening of the fish would predispose it to infection by the fungus, spores of which were no doubt widely distributed. In the case of the mackerel described here, there are, however, no external lesions, so that fungal invasion may therefore occur apart altogether from any wound of the outer surfaces of the fish's body.

Fibromatous Tumour from a Halibut (*Hippoglossus vulgaris*).

In July last, Mr. T. R. Bailey, Port Sanitary Inspector at Fleetwood, sent me part of a tumour taken from the body cavity of a halibut landed by a steam trawler. The fish was about 4 feet 6 inches in length and was in fair condition, apparently quite unaffected by the presence of the tumour. The piece of the latter sent weighed about 1,250 grams, and was rather less than half of the entire growth. It was evidently a soft fibroma, and had developed from the peritoneum covering the viscera of the fish, where, precisely, is not certain from the appearance of the structure. It was fairly soft, easily torn, clean and compact on its outer surface, which was lobulated, the diameters of the individual

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* "Note on an ulcerative disease of the Plaice." *Ann. Rept. Lancashire Sea-Fisheries Laboratory* for 1911, pp. 85-91, Pls. I. & II.

lobules varying from about $1\frac{1}{2}$ inches to $\frac{1}{4}$ inch. It came to the laboratory in the fresh condition, and parts were immediately fixed in Zenker's fluid, cut and stained in various ways.

Figs. 9 and 12, Pl. I, represent parts of the sections stained in Mann's methyl-blue-eosin. The latter figure represents the most characteristic tissue present in the growth—that is loose fibrous tissue, containing small rounded cells. The fibres run straight in the part figured, but throughout the section are places where they run in all directions. The nuclei shown in the figure are of two kinds: small elongated nuclei belonging to the connective tissue fibres, and larger rounded nuclei with a minimum of cell substance. These belong to small cells lying between the fibres.

This is, of course, quite the typical structure seen in these tumours. Fig. 9, however, shows something rather different. This figure is drawn from a section made through one of the smaller nodular masses. Here the predominant tissue consists of small rounded cells rather closely packed together, and with very few fibres. There are few blood vessels among these cells, but here and there throughout the part of the section nearest to the surface of the tumour are tubular structures. One of these is shown in the section. The internal wall consists of a layer of typical columnar cells, and outside this is a rather thick layer of coarse connective tissue, the fibres of which run concentrically round the vessel. Outside, there is no sharp distinction between the wall of the vessel and the surrounding cellular tissue. The fibres become looser and cells begin to appear between them. These vessels are quite numerous in the outer part of the tumour. They are, of course, a quite unusual feature in the histology of growths of this kind.

Melanotic Sarcomata in Skates (*Raia batis*).

Several interesting cases of this condition may be recorded. On October 15th, 1912, Mr. T. R. Bailey sent me part of the wing of a skate affected by a sarcoma. The growth occurred on the dorsal surface of the left wing. It was very nearly circular in shape and very flat, so that it looked like a large pigment patch. On closer examination, however, it was seen that the growth was slightly raised up—one or two mm., and that it was surrounded by an area of pigmentation fading rather quickly into that normal to the skin of the fish.

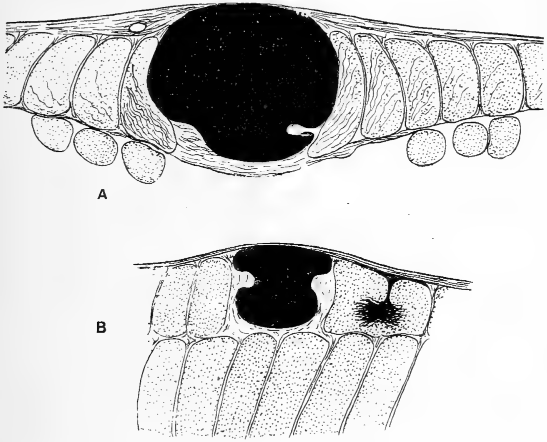
On 25th October, Mr. Bailey sent me a further specimen which illustrates the condition of melanotic sarcoma production better than any specimen I have yet seen. The fish was caught by a liner off the coast of Ireland, 45 miles N.W. from "Rathlin-a-Milley," in 70 fathoms depth. It was a skate measuring about 150 cms. (nearly 5 feet) across the body. The wings only were sent. The fish was in very poor condition, the flesh being very soft, and the fish thinner than usual. It smelt very strongly of ammonia. Mr. Bailey, however, informs me that this is not uncommon in the case of skates or rays which have gone rather "stale," though I had not noticed it in any specimens of these fish hitherto examined, nor in any skates or rays dissected in the laboratory by the students, fish which are certainly very "stale" at times. This ammoniacal odour occurs only in Elasmobranchs, under decomposition. Doubtless it is to be related to the fact that urea occurs in relatively large quantities in the blood of these fishes, and this urea may undergo conversion into ammonia compounds.

The flesh of this fish was full of melanotic tumours. There was a very large one on the dorsal surface close to the postpterygial cartilage. This measured about 15 cms. to 7 cms. in diameter, and it was raised up about 2 to 3 cms. It was very soft to the touch, having all the appearance of an enormous blister. On cutting into it a dense black fluid exuded, and the growth partially collapsed. The part of the fish containing the tumour was then cut out and hardened, and it was seen that it was a very large melanotic growth reaching down to about 6 to 7 cms. below the surface of the skin. Most of its interior was liquid, having evidently undergone extensive necrosis.

There were two other large tumours on the dorsal surface, measuring approximately about 5 to 6 cms. in diameter, and raised up 1 to 2 cms. above the general surface of the skin. They were dense black in colour, and without any appearance of integument on their upper surfaces. They were surrounded by black pigmented annular areas of skin.

There were several smaller tumours, apparently without any pigmentation, about 2 to 3 cms. in diameter and projecting about 1 cm. above the surface of the skin. On cutting through these they proved to be large melanotic growths beneath the integument, which was unaffected. They were nearly spherical in shape. Several other pigment spots on the skin also proved to be similar growths in the muscle substance beneath the integument.

Even in other parts of the fish, where there was no external pigmentation or other morbid indications, the tissues immediately beneath the skin proved to be affected. In these cases, when the flesh was cut into, there were irregular patches of dense black matter, sometimes extending along the fibrous tissue sheets separating the muscle bundles, and sometimes even diffusing into the muscle bundles themselves. In text-fig. 1, A represents the appearance of one of these larger nodular masses, natural size, and B in the same figure represents the appearance of one of the more diffuse growths. It will be seen that in A the tumour does not affect the epidermis and immediate subjacent layers, nor is the tumour raised up above the level of the skin. The muscle bundles are pushed to each side, but it is evident that the intrusive tissue, although it may have spread along the connective tissue, intermuscular septa, has invaded the substance of the muscles themselves. In the neighbourhood of these larger subcutaneous growths there may be a slight infiltration of the muscles with black pigment. This is not necessarily the growth of the sarcoma, but may merely be due to the breaking down of the latter,



Text-Fig 1. Melanotic Sarcoma in the Skate. Hand sections of part of the pectoral fin. Natural size.

and the presence of melanin granules in the lymph or blood vessels.

It is evident, then, that in this specimen we have to deal with a generalisation of the affection, since most parts of the flesh of the wings show the presence of the tumour. That this generalisation was affecting the health of the fish was very apparent from the general, bad condition of the flesh. Unfortunately, the fish had, as usual, been gutted at sea, so that there was no opportunity of examining the viscera.

The minute structure of the tumours presents several features of interest. In any specimens of skates and rays, presenting sarcomatous conditions, which I had seen before, the morbid growth affected only the integumentary connective tissues. It is true that this growth may have been massive, that is an extraordinary hypertrophy of the connective tissues may have occurred; still the underlying muscles have always been free from the morbid growth. In this specimen, however, large blocks of muscular tissue have disappeared, and their places have been taken by the sarcomatous tissue—as in Text-fig. 1.

Fig. 2, Pl. II, represents a section through the margin of one of the smaller tumours—such a section as is shown to the left in the lower figure in Text-fig. 1. On the right, in fig. 2, we see the almost unaltered muscle fibres cut in transverse section, and on the left a relatively massive aggregation of sarcomatous tissue. Even in the latter there are spaces, and these spaces contain isolated muscle fibres. On the right, the malignant tissue, indicated by its melanin contents, is seen invading the connective tissue between the fibres. In the same section of which fig. 2 is a part, the central part of the tumour is entirely free from any remains of muscle fibres, and consists entirely of the sarcomatous elements.

Fig. 6, Pl. II, shows very much the same condition, except that in this case the muscle fibres are cut longitudinally, the section is part of the edge of such a massive tumour as is represented in the upper figure (Text-fig. 1). It shows the hypertrophy of the connective tissue lying between the muscle fibres. The darkly-stippled part represents the fully-developed sarcomatous tissue: although the morbid connective tissue growth is taking place in the inter-fibrillar connective tissue, the latter is not yet loaded with melanin.

Fig. 5, Pl. II, represents some of the cells in a fully-developed part of one of the larger tumours. The structure is very obscure, but apparently consists of small rounded cells, some of which stain deeply with eosin and are very coarsely granular, while others are loaded with melanin granules. Along with these cells are masses of granules of melanin, resulting evidently from the breaking down of the pigment-containing cells. When treated for some days with hydrogen peroxide the melanin is bleached, but the cell body then stains with difficulty or not at all, and in most cases only the outer cell membrane remains visible after such prolonged bleaching.

EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Section through the renal organ of a mackerel infected with phycomycetous fungus. Large cyst with thick fibrous wall. On the left some renal tubules and lymphoid cells. The longitudinal diameter of the cyst is about 0·28 mm.

Fig. 2. The liver of the same fish; a developing spore; about 0·127 mm. in diameter.

Fig. 3. The liver of the same fish. Commencing mycelial growth of the fungus.

Fig. 4. Part of a section of the liver of the same fish. Spore-like bodies, the largest of which is about 0·065 mm. in diameter.

Fig. 5. Ovarian cysts in *Lophius.* Section of part of the thin wall of a cyst. Fine fibrous tissue with discharged goblet cells. The thickness of the wall is about 0·06 mm.

Fig. 6. Ovarian cysts in *Lophius.* Section of a thick-walled cyst. Mucous epithelium with closely-crowded goblet cells. Goblet cells about 0·04 mm. in height.

Fig. 7. Ovarian cysts in *Lophius.* Part of the section represented in fig. 6 seen under greater magnification. Fine columnar epithelium with large goblet cells.

Fig. 8. Ovarian cysts in *Lophius.* Section through one of the villus-like projections on the internal wall of a cyst. Goblet cells cut mostly at right angles to their greatest diameter. Diameter of the "villus" about 0·1 mm.

Fig. 9. Fibromatous tumour in Halibut. Tubular structure from the tumour. Thick fibrous capsule surrounding the tubule, the wall of which is composed of columnar epithelium. Outside the tubule small rounded cells. Diameter of the tubule about 0·135 mm.

Fig. 10. Fibromatous tumour in Halibut. Small, gland-like tubule from the tumour. Diameter about 0·06 mm.

Fig. 11. Ovarian cysts in *Lophius*. Gland-like structures from the submucous layer of one of the thick-walled cysts. Diameter about 0·02 mm. The darkly-stippled area in the submucous layer in fig. 6 shows the positions of these structures.

Fig. 12. Fibromatous tumour from Halibut. Part of the tumour showing its generally fibrous nature. Apochromatic lens, Zeiss, 1·5 mm.

PLATE II.

Fig. 1. Tubercular nodules in Cod. Section of the integument passing through a lesion. The oblique, dark, thick line is a scale. The darkly-stippled area is the tissues crowded with acid-fast bacilli. The thickness of the skin at the regions of the nodule is about 1·2 mm.

Fig. 2. Sarcomatous tumour from Skate. Part of the body musculature infected by the morbid growth. The light bodies are muscle fibres cut in section. The darkly-stippled area shows the *locus* of the sarcomatous tissue.

Fig. 3. Tubercular nodules in Cod. Section of a nodule stained with methyl-blue-eosin. Zeiss apochromatic 1·3 mm. Thick fibrous tissue surrounding nodules of obscure structure. The finely-stippled parts are the *loci* of the bacilli.

Fig. 4. Phycomycetous fungus in Mackerel. A group of small cysts attached to the peritoneum over the pyloric caeca. The remains of the peritoneum are represented by the fibrous structures connecting the cysts. The diameter of the largest cyst is about 0·04 mm.

Fig. 5, Sarcomatous tumour in Skate. Section of a fully-developed tumour. Rounded cells with melanin granules. Rounded cells with clear granules, or almost homogeneous cell substance. Broken-down cells and diffuse melanin granules. Zeiss apochromatic 2 mm.

Fig. 6. Sarcomatous tumour in Skate. Section of the edge of one of the larger tumours—the elongated bodies are muscle fibres in longitudinal section. The finely-stippled parts are the hypertrophied connective tissue; the darker-stippled parts represent the tumour. Zeiss AA.

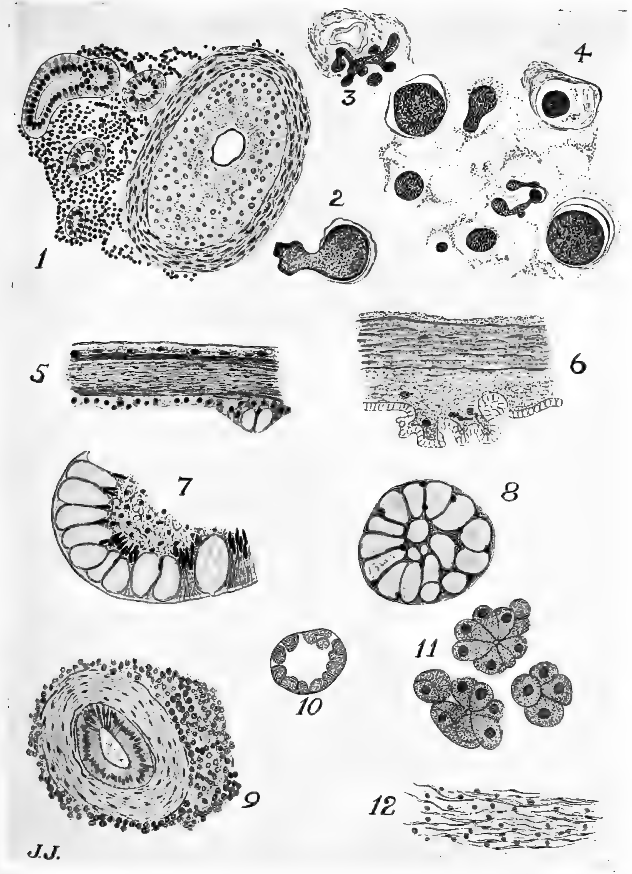
PLATE III.

Fig. 1. Ovarian cysts in *Lophius*. Natural size.

Fig. 2. Cod with tuberculous lesions in the skin. Half natural size.

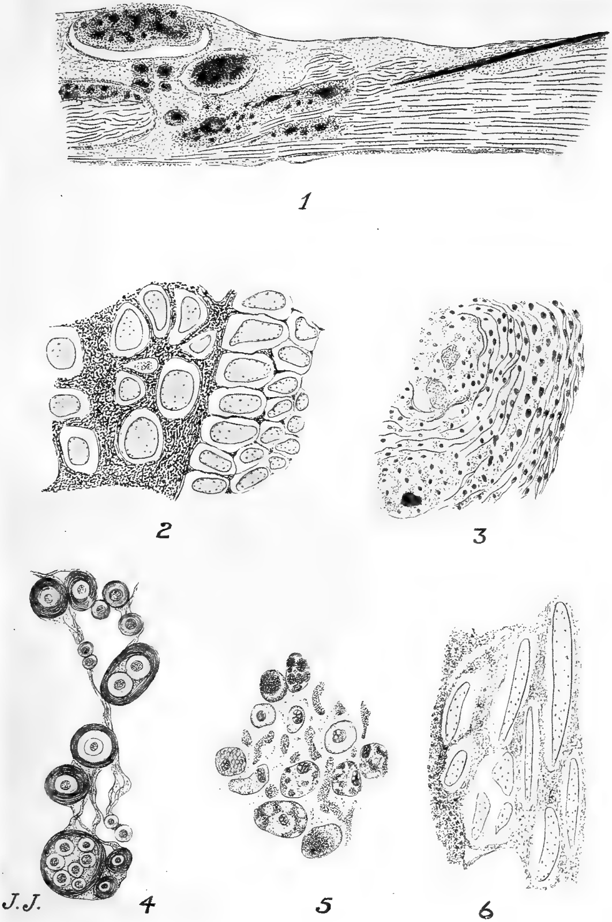
Fig. 3. Sarcomatous tumour from Skate. Hand section through part of a pectoral fin showing tumour *in situ*. Natural size.

Photos. by A. Scott.



MORBID HISTOLOGY OF FISHES.

PLATE II.



MORBID HISTOLOGY OF FISHES.

FIG 1.

FIG. 2

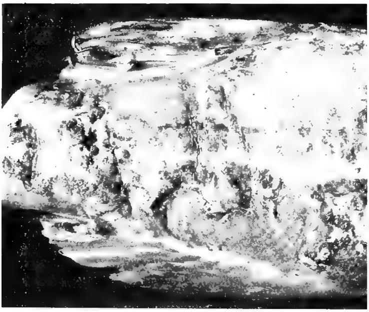


FIG. 3

Photos. by A. Scott.

MORBID HISTOLOGY OF FISHES.

A REVIEW OF PISCINE TUBERCLE, WITH A DESCRIPTION OF AN ACID-FAST BACILLUS FOUND IN THE COD.

By D. Moore Alexander, M.D.,

Assistant Lecturer in Bacteriology, The University, Liverpool.

The literature concerning the occurrence of tuberculosis amongst cold-blooded animals is extremely scanty, and with one exception relates to the inhabitants of fresh water.

In 1897 Bataillon, Dubard and Terre published an account of an organism found in a granulomatous tumour of a carp, and Terre, in 1902, reported more fully upon the subject. This bacillus was non-motile and acid-fast, its optimum temperature of growth lay between 23°-25° C., though it would grow at 12° C.; it belonged to the streptothrix family, as it showed branched forms, and in most respects agreed with the characteristics associated with the tubercle bacillus.

Apparently identical with this organism is one isolated by Möller from the spleen of a blind-worm which had been infected a year previously with the sputum of a tuberculous patient. Möller's bacillus has an optimum temperature of 22° C., development ceasing at 28° C. It grows upon ordinary agar to form a glistening white growth. In broth and upon albumen-free media it shows branching of its filaments. It is non-pathogenic for, and non-transmissible to, rabbits.

Kuster (1905) found tuberculosis in three frogs out of 200 examined. The organism grew well at 28° C., was pathogenic for frogs and other cold-blooded animals, and was toxic, but not pathogenic, for warm-blooded animals.

Weber and Taute (1906) isolated from fresh frogs, from aquarium mud, and from moss 36 strains of acid-fast bacilli, all of which were pathogenic for cold-blooded animals and harmless for warm-blooded animals.

A large amount of experimental work has been done attempting to prove, firstly, that the organism affecting cold-blooded animals is a changed tubercle bacillus; and secondly, that it is possible, experimentally, by passage through animals, to cause the tubercle bacillus of the human or bovine type to undergo a metamorphosis into the cold-blooded or piscine type.

Terre (1902), without success, injected and fed fish and frogs with cultures of human and avian tuberculosis.

Dieudonné and Herzog (1903) showed that frogs inoculated with tubercle bacilli do not die of tuberculosis, but may contain tubercle bacilli in their organs as long as 60 days after the experimental infection. They also showed that an emulsion of these organs can cause the death of a second frog, and an emulsion of its organs frequently produces a typical miliary tuberculosis when injected into a third animal. If these bacilli be now cultivated they show all the characteristics of the bacillus of piscine tubercle, being pathogenic for cold-blooded animals, but no longer for warm-blooded animals, and grow readily at room temperature. It has, however, not been possible up to the present to restore the human or bovine characteristics to these organisms, for failure has resulted from all attempts to successfully immunize a rabbit against them.

Bertarelli has produced tuberculosis in *Varanus* by sputum injection.

Hormann and Morgenroth, Nicolas and Lesieur fed fish (fresh-water) with human sputum containing tubercle bacilli without result. No tubercular lesions were ever produced in the fish, but these authors showed that acid-fast organisms were to be found in the tissues and organs of these experimental fish, and were viable for a month at least after the feeding experiments had been stopped.

The relationship between the various types of organisms characterised by the acid-fast staining reaction and isolated from cold-blooded animals, and those organisms which belong to the well-known human, bovine or avian types has been the subject of much study by many authors. The question has not as yet reached a final settlement.

Two authors alone of the many engaged in this research have succeeded in producing an organism, originally isolated from a cold-blooded animal, which they could accustom to grow at a temperature of 37°—the optimum temperature for organisims isolated from human sources. Friedmann's bacillus isolated from the lung cavity of turtles grew well at 37°, and Aujesky, after much trouble, obtained a strain of the bacillus of fish tuberculosis which would grow at the temperature of the body-heat of a warm-blooded animal, and was even pathogenic for the smaller laboratory animals.

Dubard, Bataillon and Terre believe that the bacilli of fish tubercle can become human tubercle bacilli.

Morya, Auche and Hobbs, Lubarsche, Sion and Herr do not believe that fish tubercle bacilli are produced by the passage of human tubercle bacilli through cold-blooded animals.

Sorgo and Suess have proved to their own satisfaction that human tubercle bacilli can be transmuted into the bacillus of fish tubercle.

From the point of view of this note, it is to be remarked that no close relationship between human and piscine tubercle has yet been proven, and that no work has been quoted as yet bearing upon acid-fast bacilli in *salt-water* fish. Only one paper has been found bearing on this point, by von Betegh, of Fiume, and his communication deals with experimental fish, and not with the natural occurrence in fish.

He injected varying amounts of an emulsion of a virulent culture of fish tubercle bacilli into six salt-water fish intraperitoneally or intramuscularly. The fish chosen were three *Sparus annularis*, two *Mugil cephalus* and one *Serranus gadus*. One *Sparus annularis* injected intramuscularly with 0·2 c.c. of the tubercle emulsion twenty-two days after the inoculation presented a small tumour at the site of injection. When this was incised it was found to consist of a sinus of pus and blood containing acid-fast bacilli in large clumps. At the bottom of the sinus a tubercular nodule was found showing giant cells.

The *Serranus gadus* injected intraperitoneally with 0·2 c.c. of the emulsion developed tuberculosis of the swim bladder. All the other organs were found to be normal. None of the other fish injected showed any symptoms.

PRESENT INVESTIGATION.

In November, 1912, a portion of a cod obtained at Fleetwood was sent for bacteriological examination. The surface of the fish presented six dark-coloured areas suggestive of lupus in the human subject, and varying in size from a threepenny-piece to that of a florin.

After a thorough washing with sterile saline, an aseptic instrument was employed to scrape the patches thoroughly. The resulting débris was deposited in three bottles labelled A, B and C.

Bottle A.—The contents of this bottle were covered with 20 % antiformin solution, which consists of equal parts of soda chlorinata and 15 % liquor sodae, and possesses the property of destroying all other organisms but those which are acid-fast. After remaining in this solution for one hour the deposit was thoroughly washed with sterile saline to remove the antiformin, and then inoculated into twelve tubes of Dorset's egg medium, and incubated at room temperature.

Bottle B.—The contents of this bottle were treated as in Bottle A, but after thorough washing were injected into two guinea-pigs subcutaneously.

Bottle C.—The contents of this bottle were emulsified in sterile saline and injected into two guinea-pigs subcutaneously. Some large pieces of tissue which could not be broken up into a satisfactory emulsion were inserted under the skin of the abdomen of two guinea-pigs.

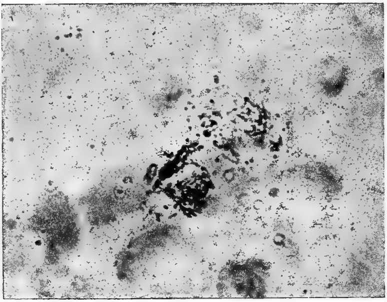
Since the bacillus of tuberculosis found in cold-blooded animals rarely possess any pathogenicity for the ordinary laboratory animals, there was no expectation that generalised tuberculosis would result in the guinea-pigs. These animals were inoculated in the hope that they would serve as an incubator, and were examined every few days for glandular enlargements and for any lesion at the site of inoculation.

Only the two animals inoculated with large portions of tissue, untreated with antiformin (Bottle C), showed any reaction. A week after inoculation both animals presented a swelling at the point of injection about the size of a broad-bean. The examination of the two guinea-pigs was conducted on different lines.

G. P. 37. Thirteen days after inoculation the swelling burst, discharging a creamy caseous pus, and showed a tendency to form an ulcer. The animal was in good health. It was killed, and a thorough post mortem made after smears and cultures had been made from the pus. All the internal organs were healthy.

The pus was found to consist almost entirely of polymorphonuclear leucocytes. Many of these were filled with acid-fast bacilli congregated in clumps or bundles consisting of from twenty to forty separate individuals.

The microphotograph shows the arrangement of these clumps, and also a few organisms lying outside the leucocytes.



The second animal inoculated from Bottle C (G. P. 38) with actual masses of the fish-material showed no tendency to ulceration, and was kept under observation for five weeks. The swelling at the site of inoculation showed at no time any tendency to burst, and soon diminished in size until on the 38th day after inoculation, when the animal was killed and examined, no trace of the injection except a small nodule of scar tissue was to be found. This scar tissue on section presented the appearance of chronic inflammatory fibrous tissue, and no acid-fast bacilli were present. No internal lesions were found.

The other four guinea-pigs (G. P. 34, 35, 36, 43) inoculated from the emulsified contents of Bottles B and C at no time showed symptoms, were killed on the 38th day after inoculation and presented no lesions.

The cultural results have been unsuccessful in that a pure culture of the organism has not been obtained, and hence it has been impossible to study fully its relationship to human tubercle and the other acid-fast bacilli. The organism has been kept alive, but only in a symbiosis with a Gram-positive coccus. When dilutions are attempted to produce a pure culture the organism dies out at once.

CONCLUSIONS.

It has been shown that an acid-fast bacillus is present in a skin affection of a cod resembling lupus and containing typical tubercles. The organism is non-pathogenic for the guinea-pig, and does not grow at 37° C. It grows at room temperature, but so far only in symbiosis with a coccus.

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REPORT ON THE HYDROGRAPHIC, PLANKTONIC AND OTHER PERIODIC CRUISES OF THE "JAMES FLETCHER" IN 1912.

By W. Riddell, M.A.

The positions of the various Stations are shown in the chart on page 234. Surface temperatures and water-samples were taken at all Stations.

At Stations 5, 6, and 7, water-samples and temperatures were also taken, except where the contrary is stated, at 30 metres and near the bottom.

For the deep samples, the Nansen-Pettersson insulated water-bottle was used in the earlier cruises. Since September the Ekman reversing water-bottle has been used.

The plankton samples were taken with the Nansen vertical net of No. 20 silk and with surface horizontal tow-nets.

MAY, 1912. Quarterly hydrographic cruise.

May 7th.—Worked Stations 1-7. At Station 7 samples were obtained only at surface and 30 metres. A vertical plankton haul was made at Station 6. Surface temperatures were also taken at Piel Gas Buoy, at the Skerries, and between the Stations.

May 8th.—Stations 8-13. Surface temperatures between Stations, and at Carmel Point, Middle Mouse and Point Lynus. Ran to West of Isle of Man, and trawled 7 miles W. of Contrary Head; townetting while trawling.

May 9th.—Stations 14-21. Surface temperatures between Stations, also off Piel and in Ramsey Bay.

May 10th.—Stations 22-24. Also surface temperatures between Stations, and at Bahama Bank Lightship and Lune Buoy.

JUNE, 1912. Monthly hydrographic cruise.

June 3rd.—Stations 1-4. Surface temperatures at Piel Gas Buoy and between Stations.

June 4th.—Stations 5-7. Plankton hauls at each Station and half-way between Stations. Surface temperatures between Stations, and off Douglas Head and Langness.

June 5th.—Trawling and marking plaice off Nelson Buoy. 212 fish marked, ranging in size from 19 to 36·5 cm.

June 6th.—Trawling off Selker Lightship; large haul of plaice measured.

JULY, 1912. Monthly hydrographic cruise.

July 1st.—Stations 1-4. Surface temperatures at Piel Gas Buoy and between Stations.

July 2nd.—Stations 5-7. Plankton hauls at each Station. Surface temperatures between Stations and off Douglas Head, Langness, Skerries and South Stack. Townetting in Carnarvon Bay while trawling.

July 3rd.—Shear-net plankton hauls at various localities in Carnarvon Bay and Cardigan Bay.

July 4th.—Shear-net hauls at various localities in Cardigan Bay. Ordinary surface haul while trawling.

JULY, 1912. Quarterly hydrographic cruise.

July 29th.—Stations 1-4. Surface temperatures at Piel Gas Buoy, between Stations, and off Langness.

July 30th.—Stations 5-13, omitting 8 and 9. Plankton hauls at 5, 6 and 7. Surface temperatures between Stations, off Skerries, and on course from Station 13 to Ramsey.

July 31st.—Stations 14-24. Surface temperatures between Stations, off Point of Ayre, and at Lune Buoy.

SEPTEMBER, 1912. Monthly hydrographic cruise.

September 10th.—Stations 1-4. Surface temperatures between Stations, at Piel Buoy and off Langness.

September 11th.—Stations 5-7. Plankton hauls at each Station. Surface temperatures between Stations and off Skerries.

September 12th.—Shear-net hauls in Carnarvon Bay and Cardigan Bay.

September 12th.—Trawled off Liverpool Bar. Good haul. 203 plaice measured.

OCTOBER, 1912. Monthly hydrographic cruise.

October 7th.—Stations 1-4. Surface temperatures between Stations, at Piel Buoy and off Langness.

October 8th.—Stations 5-7. Plankton hauls at each Station. Surface temperatures between Stations, off Calf of Man, off Skerries and off South Stack. Shear-net haul in Cardigan Bay.

October 9th.—Trawled in Red Wharf Bay. Fair haul. 68 plaice measured.

October 10th.—Trawled in Conway Bay. Big haul. 1,200 plaice measured.

FIRST LUCE BAY TRIP.

October 21st.—Ran from Piel to Luce Bay.

October 22nd.—Trawling in Luce Bay; 13 hauls. Put 230 fish in tanks.

October 23rd.—Landed 100 fish at Port Erin for Hatchery; remainder taken on to Piel and landed in evening.

NOVEMBER, 1912. Quarterly cruise.

November 4th.—Stations 1-4. Surface temperatures at Piel Buoy and between Stations.

November 5th.—Stations 5-7. Plankton hauls at each Station. Surface temperatures between Stations and off Douglas Head, Langness and Skerries.

November 6th.—Stations 8-13. Surface temperatures between Stations, and at Carmel Point, Middle Mouse, Point Lynus and Douglas Head.

November 7th.—Stations 14-21. Surface temperatures between Stations, and at Point of Ayre.

November 8th.—Stations 22-24. Surface temperatures between Stations, and at Maughold Head and Piel Gas Buoy.

SECOND LUCE BAY TRIP.

November 19th.—Fleetwood to Luce Bay. Trawled on Bahama Bank; fish scarce.

November 20th.—Trawled in Luce Bay; 10 hauls. Put 171 fish in tanks.

November 21st.—Landed fish at Port Erin. Ran to Red Wharf Bay and trawled; fish scarce.

DECEMBER, 1912. Monthly hydrographic cruise.

December 3rd.—Stations 1-4. Surface temperatures between Stations, and at Piel Gas Buoy and off Langness.

December 4th.—Stations 5-7. Surface temperatures between Stations, and off Skerries. Plankton hauls at each Station.

December 5th.—Trawled in Red Wharf Bay, Conway Bay, and off Rhyl Patches. Fish very scarce.

JANUARY, 1913. Monthly hydrographic cruise.

January 7th.—Stations 1-4. Surface temperatures between Stations, and at Piel Buoy.

January 8th.—Stations 5-7. Plankton haul at each Station. Surface temperatures between Stations and at Douglas Head, Langness and Skerries.

January 9th.—Trawled off Point Lynus and in Red Wharf Bay; fish scarce.

January 10th.—Trawled off Colwyn; few fish.

FISH-EGG CRUISE.

January 20th.—Trawled 10 miles East of Point Lynus; tow-net out while trawling. Townetted off Carnarvon Bay Lightship.

January 21st.—Trawled off Penkilan Head, using tow-net. Townetted in Tremadoc Bay, and 22½ miles S.S.W. from Bardsey Island.

January 22nd.—Trawled, using tow-net, off Patches Buoy and off New Quay Head.

January 23rd.—Trawled and townetted 25 miles W.N.W. from Piel Buoy and off Maughold Head.

FEBRUARY, 1913. Quarterly hydrographic cruise.

February 3rd.—Left Fleetwood, but owing to wind had to shelter in Piel.

February 4th.—Stations 1-4. Surface temperatures between Stations and at Piel Gas Buoy. Trawled and townetted 25 miles W.N.W. from Piel Buoy.

February 5th.—Surface samples at Stations 5-8. No deep samples taken owing to heavy sea. Surface temperatures between Stations, and at Douglas Head, Langness and off Skerries.

February 6th.—Stations 9-13. Surface temperatures between Stations.

February 7th.—Stations 14 and 17-21; Stations 15 and 16 were omitted owing to bad weather Surface temperatures between Stations.

February 8th.—Stations 22A-24A, from 1 to 2 miles away from Stations 22-24, on line from Maughold Head to Piel Gas Buoy. Surface temperatures between Stations, and at Maughold Head and Piel Gas Buoy.

FISH-EGG CRUISE.

February 18th.—(Mr. Ray was in charge of the scientific work on this trip.) Trawled 25 miles W.N.W. from Piel Gas Buoy, and on line between Bahama Bank and Selker Lightship (three hauls). Vertical hauls were taken with a coarse plankton net at Morecambe Bay Lightship, between this and Bahama Bank, at Bahama Bank, between Bahama Bank and Selker Lightship, and at Selker Lightship. Surface hauls were taken at the same Stations, and also when trawling.

February 19th.—Trawled 5 miles W. by S. from Selker Lightship, using surface tow-net while trawling. Landed fish at Piel.

February 20th.—Used shrimp-net on Blackpool grounds, using surface tow-net at same time, also 1 mile S. of Blackpool grounds.

February 24th.—Trawled and townetted at following places:—Duddon Buoy, 1 mile S. of Duddon Buoy, and 10 and 12 miles W. from Duddon Buoy.

February 25th.—Trawled and townetted 20 miles N.W. 1/2 N. from Piel Gas Buoy, and 24 miles W.N.W. from same. Landed fish at Piel.

February 26th.—Trawled and townetted 10 and 15 miles S.W. from Morecambe Bay Lightship; also townetted 10 miles N. of Great Orme's Head.

MARCH, 1913. Monthly hydrographic cruise.

March 3rd.—Trawling for fish for Piel. Trawled and townetted 15, 18 and 22 miles W.N.W. from Piel Gas Buoy. Fish scarce. Landed fish at Piel.

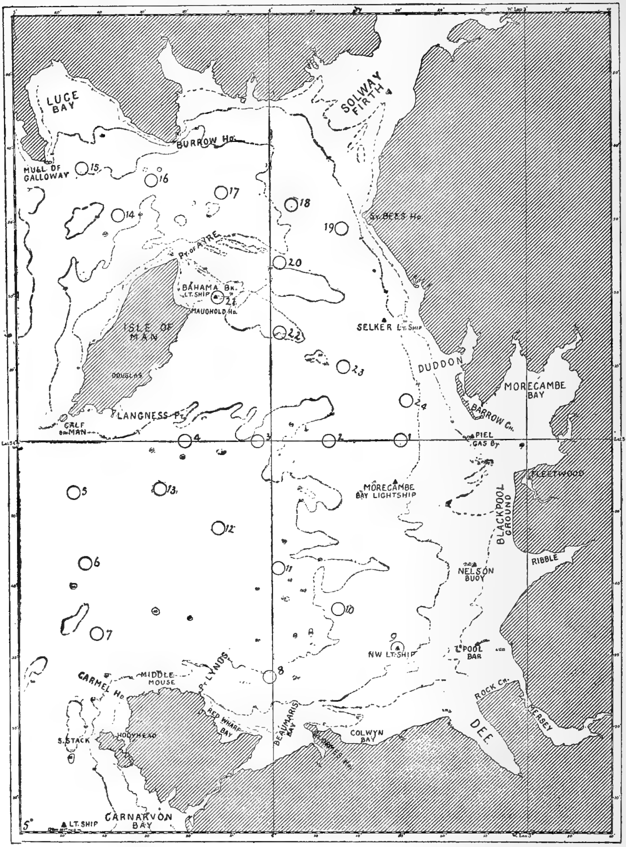
March 4th.—Surface samples and temperatures at Stations 1-4. Surface temperatures at Piel Gas Buoy and between Stations.

March 5th.—Stations 5-7. Plankton hauls at each; catch at Station 5 lost by tearing of silk on bucket of net. Surface temperatures between Stations, and off Langness and the Skerries.

March 6th.—Trawled and townetted 5 and 10 miles E. of Point Lynus. Fish scarce.

The plankton samples of these cruises will be reported on by myself in a separate paper below. The water-samples and temperature observations will be discussed by Mr. Johnstone and Professor Bassett. The records of marked and other fish will also be dealt with elsewhere in this report.

[Chart showing stations over page.]



Observation Stations in 1912.

REPORT ON THE PLANKTON OF THE PERIODIC CRUISES OF THE "JAMES FLETCHER" IN 1912-13.

By W. RIDDELL, M.A.

The plankton observations made on the "James Fletcher" during the year may be divided into two series. There are first the routine vertical hauls made with the Nansen closing net, 35 cm. in diameter, of number 20 silk. These hauls are made regularly on the hydrographic cruises at the following Stations; (see chart on p. 234); at Stations 5, 6 and 7 on all cruises, and at Station 14 on the quarterly cruises The net is lowered to 20 fathoms and then hauled vertically to the surface. There are also a considerable number of horizontal hauls made either with the ordinary surface tow-net of book-muslin, or with a shear-net of embroidery canvas. These have been taken at various places throughout the district.

NANSEN NET OBSERVATIONS.

Unfortunately we have not as complete a series of these as we had wished for. Owing to various causes involved in the starting of a new scheme, and especially to unavoidable delay in obtaining the new nets from the manufacturers, we were not able to use a standard net until the second quarterly cruise, which was carried out during the end of July and beginning of August. Various temporary substitutes were used on the earlier cruises, but these, while giving some indication of the nature of the plankton present, cannot be used for comparison with the later hauls. Further, the weather during the cruise at the beginning of February, 1913, was so bad that we were unable to use our nets.

We have thus only 22 hauls which are strictly comparable, 2 hauls at Station 14, 7 each at Stations 6 and 7, and 6 at Station 5.

If we consider first the two hauls at Station 14, in the northern part of our district, we shall see that they show a marked difference.

Station 14.	31st July, 1912.	7th Nov., 1912.
Calanus finmarchicus	50	17
Pseudocalanus elongatus	1,400	1,450
Acartia clausi	950	200
Oithona similis	550	300
Temora longicornis	250	—
Nauplii	3,100	1,350
Sagitta bipunctata	80	2
Tomopteris helgolandica	1	—
Polychaet larvae	—	100
Medusoids	8	1
Pleurobrachia pileus	—	1
Tintinnidae	—	1,450
Noctiluca miliaris	—	100
Oikopleura dioica	150	—
Peridinium divergens	150	—
Ceratium furca	150	100
,, fusus	5,300	100
,, intermedium	4,700	725
Asterionella japonica	—	300
Biddulphia regia*	—	950
,, sinensis	—	520
Chaetoceras debile	—	625
,, decipiens	—	2,800
,, densum	450	400
,, didymum	—	500
,, schüttii	—	4,150
Coscinodiscus concinnus	—	100
,, radiatus	600	625
Ditylium brightwellii	—	200
Guinardia flaccida	8,000	—
Rhizosolenia semispina	3,750	—
,, shrubsolei	11,400	—
,, stolterfothii	224,700	—
Streptotheca thamensis	—	400
Thalassiosira gravida	—	1,150

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* This does not imply that this form is to be regarded as a distinct species from *B. mobiliensis.*

The haul on the 31st of July shows a well-marked autumn plankton, consisting mainly of Copepods, Dinoflagellates, and *Rhizosolenia.* On November 7th there is a decrease in the numbers of Copepoda, and a marked decrease in the Dinoflagellates, while *Rhizosolenia* has disappeared and been replaced by other Diatoms. We may note here that a surface haul in Luce Bay on October 22nd showed *Rhizosolenia* still present in the inshore waters in fair numbers, but other forms, *Biddulphia, Chaetoceras, Ditylium* and *Thalassiosira,* had also made their appearance. This succession of forms in autumn corresponds to what has been observed at Port Erin.

If we contrast these two hauls with those taken at the more southerly Stations (5, 6, 7) on corresponding dates, we shall see that while there are some points of resemblance there are also some marked distinctions. As regards Copepoda the result is much the same, the drop in numbers being, however, more marked at the southern Stations. At both localities *Pseudocalanus* is the most common Copepod in November, while *Temora* has disappeared. *Sagitta* also shows a correspondence. *Rhizosolenia,* however, is different, being still present at the southern stations in November.

But the most marked difference is in the Dinoflagellates; here the two localities show directly opposite conditions. At the southern Stations Dinoflagellates, except *Peridinium,* were absent at the end of July, while in November they appear to be at their maximum. They are still present in March.

The Tintinnidae also show some resemblance. At Station 14 these were absent in July, and present in fairly large numbers in November. At the southern Stations they were present in July at Station 5 only, and in comparatively small numbers. In November they are present in large numbers, though they appear to have

Date	July 30th, 1912.			Sept. 11th, 1912.		
Station	5	6	7	5	6	7
Calanus finmarchicus	600	130	14	45	40	40
Pseudocalanus elongatus	4600	3500	300	6000	2600	750
Temora longicornis	3750	1150	200	—	—	100
Acartia clausi	5600	2300	200	3000	900	200
Oithona similis	400	200	—	450	300	—
Nauplii	12700	8800	2700	4000	3400	4200
Podon intermedium	—	—	—	150	—	—
Decapod larvae	—	—	—	—	1	1
Euphausid larvae	—	—	—	—	—	—
Sagitta bipunctata	32	22	12	23	12	34
Tomopteris helgolandica	—	—	3	—	1	—
Polychaet larvae	—	520	—	—	—	1600
Echinoderm plutei	—	100	—	150	—	—
Medusoid gonophores	10	—	2	—	—	—
Noctiluca miliaris	—	—	100	—	—	—
Tintinnidae	400	—	—	6250	1700	400
Dictyocha fibula	—	—	—	—	—	—
Oikopleura dioica	100	300	100	300	300	—
Peridinium spp.	830	100	—	—	—	—
Dinophysis acuta	—	—	—	—	—	—
Ceratium furca	—	—	—	—	—	—
,, fusus	—	—	—	—	—	—
,, intermedium	—	—	—	150	—	—
,, longipes	—	—	—	—	—	—
,, tripos	—	—	—	—	—	—
Actinoptychus undulatus	—	—	—	—	—	—
Asterionella japonica	—	—	—	—	300	200
Bacillaria paradoxa	—	—	—	—	—	—
Biddulphia aurita	—	—	—	—	—	—
,, mobiliensis	—	—	—	—	—	—
,, regia	—	—	—	150	150	200
,, sinensis	—	—	—	—	—	—
Chaetoceras contortum	—	—	—	—	—	—
,, criophilum	—	—	—	—	—	—
,, debile	—	—	—	—	—	—
,, decipiens	—	—	1350	—	1850	600
,, densum	—	13400	1600	4400	6750	850
,, schuttii	—	—	—	—	—	—
,, sociale	—	—	—	—	—	7550
,, teres	—	—	—	—	—	—
Coscinodiscus concinnus	—	—	—	—	—	—
,, grani	—	—	—	—	—	—
,, radiatus	400	400	100	300	750	500
Ditylium brightwellii	—	100	100	—	150	200
Eucampia zodiacus	—	—	—	—	—	—
Guinardia flaccida	—	1000	4400	—	—	1350
Lauderia borealis	—	—	—	—	—	33600
Rhizosolenia semispina	—	300	1000	—	—	—
,, setigera	—	—	—	—	—	—
,, shrubsolei	—	1600	2100	300	—	—
,, stolterfothii	—	200	1000	450	—	—
Streptotheca thamensis	—	—	—	—	—	—
Thalassiosira gravida	—	—	—	—	—	—
Thalassiothrix nitzschioides	—	—	—	—	—	—

Oct. 8th, 1912.			Nov. 5th, 1912.			Dec. 4th, 1912.			Jan. 8th, 1913.			Mar. 5th, '13.	
5	6	7	5	6	7	5	6	7	5	6	7	6	7
2	50	8	7	—	4	20	5	3	5	—	—	—	1
150	1250	200	1250	200	100	1000	300	100	150	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
200	850	100	450	—	—	200	—	200	—	—	—	—	—
100	625	100	150	—	—	200	75	—	375	—	—	100	—
1250	2300	1250	1250	1250	725	750	75	625	375	—	200	500	200
—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	3	—	—	—	—	—	—	1	—	—	—	—	—
—	—	1	—	—	—	—	—	—	—	—	—	—	—
—	5	2	—	2	5	1	3	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	200	100	—	—	—	100	—	—	75	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	5	—	.2	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	300	—	—	—	—	—	—	—	—
13700	16000	5400	12000	1500	3000	1750	600	1250	675	300	100	100	500
100	—	—	625	200	—	—	—	—	—	—	—	100	—
200	—	—	—	—	—	—	—	—	—	—	—	—	—
100	—	—	625	200	—	—	—	200	—	—	—	—	—
—	—	—	300	—	—	—	—	—	—	—	—	—	—
—	200	—	2350	100	600	1500	375	200	225	600	500	100	200
100	—	400	800	200	700	300	150	—	75	200	200	200	—
—	—	700	4000	1000	2700	750	700	200	225	400	500	—	—
—	—	—	300	—	—	—	—	—	—	—	100	200	—
100	200	—	—	—	—	200	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	200	—	—
1450	7000	3000	5300	1850	200	—	75	300	—	—	—	—	—
700	—	—	3000	—	—	—	—	—	—	—	—	1100	2000
—	—	—	—	—	—	—	—	—	—	—	—	—	200
—	200	300	625	200	300	300	150	—	75	200	—	1450	1150
100	400	2400	2000	1850	2300	850	1000	3800	825	1350	700	9600	6600
—	—	—	150	—	—	1550	600	100	375	—	—	—	—
2100	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	625	—	—	—	—	—	—	—	—	—	—
1000	—	6600	—	625	400	—	—	—	—	—	—	—	—
7300	12500	1550	10300	3200	—	2200	825	7200	—	—	—	—	—
1750	625	500	3000	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	400	—	—	—	—	—	—	—
1550	3000	12500	—	—	1600	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	600
—	—	500	—	—	200	400	—	—	75	—	100	400	200
—	—	200	—	—	—	—	—	—	—	—	—	—	—
100	625	1000	1000	520	800	1000	750	1000	1000	1850	2000	2700	2400
3200	3300	1700	1500	1350	600	300	200	100	—	75	—	400	500
1850	—	—	—	—	—	—	—	—	—	—	—	—	400
—	—	3800	—	—	3000	—	—	500	—	—	—	400	—
—	625	—	625	2000	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	600	450	200	1350	—	—	—	—	—	100	—	100
—	200	1250	150	200	300	—	—	—	—	—	—	100	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
300	500	9400	7000	10500	7300	4000	1800	13200	375	3750	3000	15600	8650
725	—	300	2650	5000	7600	—	1000	1000	—	1850	3700	4400	8400
—	1850	800	—	400	100	—	—	—	—	—	—	500	300

reached their maximum in October. In both regions, also, *Oikopleura* was present, though not in large numbers, in July, but was absent in November.

As regards Diatoms there is also fair similarity. *Rhizosolenia* has already been noticed. In both localities *Asterionella*, *Biddulphia*, *Streptotheca* and *Thalassiosira* were absent in July, present in November. On the other hand, *Guinardia* is absent from Station 14 in November, but still present at Station 7 (the most southerly). The various species of *Chaetoceras* also show some resemblance. Their maximum seems to have occurred at the southern Stations in October. A comparison of the three southern Stations with each other does not appear to show much of interest. It is possible, however, that a more extended series of observations will give better grounds for comparison. One or two forms may be noted. Thus *Noctiluca* only occurs twice, both times at the most southerly of the three Stations. This agrees with what has been previously observed in our district, that *Noctiluca* is largely confined to the inshore waters along the Lancashire and North Wales coasts. *Biddulphia sinensis*, which now appears to be an established form at Port Erin, is most common at Station 5, where it occurs from November to January. It only occurs at Stations 6 and 7 in December, and on this date was most abundant at Station 5, much less common at 6, and least at 7. This looks as if its occurrence was due to a spreading from the south of the Isle of Man. On the other hand, *Rhizosolenia setigera* is most common at Station 7. It only occurs once at 5 and 6, and on this date is much more abundant at 7. *Thalassiothrix nitzschioides* never occurred at Station 5. On the other hand, it was more common at 6 than at 7.

OTHER OBSERVATIONS.

There are a number of other tow-nettings, taken with either an ordinary surface net or the shear net, from various localities throughout the district. I do not propose to consider these in detail, but shall merely offer a few notes on some of the organisms found in them.

Muggiaea atlantica occurs in four of our catches. It was first observed on September 12th, on which day it occurred in the following localities:—4 miles N.E. of Carnarvon Bay Lightship; 5 miles S. of Carnarvon Bay Lightship; 3 miles N. of Causeway Buoy, Cardigan Bay. All these hauls were made with the shear net, about 10 fathoms deep. It was most abundant in Cardigan Bay, but was also in fair quantity in Carnarvon Bay. Another catch made on this date, further south in Cardigan Bay, was unfortunately lost by breakage of the bottle in transit from Fleetwood to Liverpool. The other gathering in which *Muggiaea* occurs is a shear-net haul made near Causeway Buoy on October 8th. It did not occur in any other Cardigan Bay catches on this date, and there are no catches from Carnarvon Bay for this month. This is the first time *Muggiaea* has been observed so far north in our waters.

Autolytus prolifer occurred sparsely in various localities during most of the period. In the second half of January swarms of pelagic males and females were encountered in three localities:—Near Carnarvon Bay Lightship; off Maughold Head, Isle of Man; and about half-way between Morecambe Bay and the Calf of Man. In Cardigan Bay, at the same period, only a few individuals, all males, were taken. In most of the females the ova were in a pretty advanced condition, and in some they had evidently recently hatched out, a few embryos, of three or four segments, being still in the remains of the egg-sacs and others free in the gathering. Other swarms, consisting almost entirely of males, were found 15 miles S.W. from Morecambe Bay Lightship, February 26th, and 10 miles E. of Point Lynus, March 6th.

COPEPODA.—The species most constantly present throughout our district appear to be *Calanus finmarchicus*, *Pseudocalanus elongatus* and *Acartia clausi*. Of these the most constant in point of numbers is *Pseudocalanus*. These three species occur in most of our hauls, being more abundant in summer. In Cardigan Bay and Carnarvon Bay the most abundant form during the summer was *Temora longicornis*. *Oithona similis* was rare in this part of the district, but was more common in the northern part, where it occurred more constantly than *Temora*, though never in as large numbers. *Centropages hamatus* was taken in Cardigan Bay and Carnarvon Bay in fair quantity during the summer; *C. typicus* also occurred, though much less commonly. Neither of these was found in any of our hauls further north. *Anomalocera pattersoni* occurred in various localities, both north and south, from June onwards, but was always scarce. *Isias clavipes* and *Candacia armata* were taken in Carnarvon and Cardigan Bays during the summer, the former being sometimes fairly common, the latter always rare.

EUPHAUSIACEA*.—*Nyctiphanes couchii* was taken on two or three occasions, in Red Wharf Bay and Carnarvon Bay; it seems not uncommon in this part of the district. A fair number of Euphausid larvae, in various stages, were found in Carnarvon Bay from July until September, and are probably referable to this species. *Mega-*

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* I have to thank Dr. W. M. Tattersall for much kind help in connection with the Euphausiacea and Mysidacea.

nyctiphanes norvegica was taken 10 miles W. of Duddon Buoy, on February 24th, and 15 miles S.W. of Morecambe Bay Lightship, on February 26th.

Mysidacea.—*Gastrosaccus spinifer* was taken in large numbers in Red Wharf Bay on December 5th, after sunset. One specimen of *Anchialina agilis* was taken in Carnarvon Bay on January 20th. This is the first time this species has been found in our district. One specimen of *Siriella armata* was taken in Luce Bay on October 22nd. A few *S. norvegica* were taken between Selker Lightship and Bahama Bank on February 18th. *Macromysis* (*Praunus*) *inermis* was taken in Red Wharf Bay on December 5th, after sunset. A few specimens of *Macropsis slabberi* were taken in a surface haul near Duddon Buoy on February 24th. This appears to be the first record of this species from this coast.

Decapoda.—Decapod larvae were extremely abundant in Carnarvon Bay and Cardigan Bay from July until October. Many of these have not yet been identified, but the following may be noted.

The larvae of *Pandalus montagui* and *Pandalina brevirostris*, in various stages, were common. The larva of *Pandalus bonnieri* was taken in Carnarvon Bay on July 3rd. *Hippolyte varians* occurred only once, the first post-larval stage being taken near Causeway Buoy on July 4th. The larvae of *Crangon vulgaris* occurred in many gatherings, but never in large numbers. The larvae of a species of *Leander* occurred in small numbers at three or four Stations in Cardigan Bay. I am inclined to identify these as *Leander adspersus*, as they agree very closely with Mortensen's description. If this is correct, this species must be more common in our waters than had previously been supposed.

One "*Phyllosoma*" was taken at Causeway Buoy on July 4th. The larvae of *Jaxea* were abundant in Tremadoc Bay on July 3rd. *Callianassa* larvae occurred in several of the gatherings in Carnarvon Bay and Cardigan Bay in July.

A haul taken off the Selker Lightship in June was largely composed of zoeas of *Corystes cassivelaunus.*

Other larvae which occurred frequently during summer and autumn were those of *Galathea*, *Munida*, *Porcellana*, *Eupagurus* and *Portunus.* No adult Decapods were taken in any of the gatherings.

CEPHALOPODA.—Young specimens of *Loligo media*, up to about 12 mm. in length, were common in Cardigan Bay and Carnarvon Bay during July and August.

FISH EGGS.—These are being worked up by Mr. Scott. I shall merely note here the occurrence of eggs of the Anchovy in Tremadoc Bay on July 3rd, and the appearance of eggs of *Callionymus* off Maughold Head so early as the end of January.

At the present stage of the work, I prefer not to attempt to draw any conclusions as to the relation between the plankton and hydrography. It is quite possible, however, that a more extended series of observations may enable us to show that some connection exists.

REPORT ON PLAICE MEASUREMENTS MADE DURING THE YEAR 1912.

By Jas. Johnstone, B.Sc.

This Report deals with measurements of plaice made during the year 1912, and forms a continuation of the similar measurements made during the last four years. The primary object of these investigations was to provide data for a rational discussion of the effects likely to follow from the adoption of the 6-inch trawl mesh in place of the 7-inch mesh—a question of considerable local importance during the last few years. The data already accumulated have proved sufficient for this purpose, but the measurements have been continued for several reasons: (1) it is hoped that they may be useful in future investigations by providing fairly accurate data as to the modal lengths of plaice on the fishing grounds at various seasons; such information, if it had existed for (say) the year 1870, would now be of the greatest interest. (2) A study of the variation in length on the various grounds is of assistance in the interpretation of the results of the marked-fish experiments, and, in general, the problem of plaice migrations. (3) It is hoped that they will provide data for the determination of the lengths of plaice at different ages, and of different sexes, and for that of the age and length at which these fish become sexually mature for the first time. (4) The estimates of the "condition" of the fish, that is, the values of the coefficient *k* may be of service in a study of the relationship between the physical conditions of the sea and the rate of metabolism of the fish.

The arrangement of the data is much the same as in previous years. The length-frequencies are first given.

In these tables the unit of length is the centimetre; and the numbers of fish measured refer to means of length: thus all the fish between n cms. and $n + 1$ cms. are grouped as $n{\cdot}5$ cms. Tables of sex and age are also given: the notation for the age-groups adopted is that usually employed, that is, all fish under one year of age are included in the group "O"; those over one year and under two years of age are included in group "I," and so on. Generally speaking, the plaice in Lancashire inshore waters belong to groups O, I, II, and III.

Summaries of these age-determinations are given in the tables on pp. 267-8. In the table on p. 267 the sexes are distinguished. But in that on p. 268 they are grouped together. This is because the latter table includes a considerable number of plaice belonging to age-group O, and the smaller fish in this group require a rather detailed examination if the sex is to be determined with certainty. Also the difference in the rate of growth in the two sexes of plaice under about 10 cms. is quite insignificant, so that the combination of the figures does not matter.

Although well over 10,000 plaice have been examined in detail during the last four years, and their sex and age determined, it is still impossible to say what is the mean or modal lengths of Irish Sea plaice at the end of each year of age up to the fifth year. The table on p. 268 shows that the mode in age-group O lies apparently about length 7 and this is probably very near the truth. That of age-group II is near 19 cms., and this estimate also is very nearly accurate. The modes in age-groups III and IV cannot be determined merely by inspection of the frequencies, and, indeed, the numbers of fish in Group IV are too small to be used for statistical purposes. In Group I the mode lies somewhere near length 17 cms., so that there is apparently an increment of growth of about 10 cms. between Groups O and I, and an increment of only 2 cms. between Groups I and II. After examining some of my figures, Professor D'Arcy Thompson suggested that a complete year had been omitted in these estimates: if this were really the case, it would seem that the method of age-determination by the examination of the growth of the otolith is unreliable. Scrutiny of the table shows, however, that the cause of the apparent irregularity really lies in the method of sampling which had to be employed.

The ranges in the cases of Groups I to III are probably very approximately given by the table. Group IV has, doubtless, a more extended range than that shown, since very few fish over 40 cms. in length have been examined, and a larger number would probably show that plaice of this age may be much larger than 41·5 cms. The lower limit of plaice of Group O is, of course, at zero length. In the case of Groups I to IV the lower limits are probably as they are shown in the table. In Group II the distribution is markedly skew, and this is also apparent in Group III, but not to the same extent, while in Group IV the distribution about the mean is probably symmetrical. Group I ought to be still more asymmetrical than Group II, and obviously in Group O the mode will be at infinity. Yet the actual figures show that the distribution of frequencies in Group I is very nearly symmetrical.

The reason of the irregularity in the case of plaice of Group I is that the ordinary 6-inch trawl mesh does not give a catch of plaice representative of those resident on the sea bottom in shallow waters, such as those of Lancashire. Thus there are far too few at lengths of 8 to about 15 cms., fish of these sizes escaping through the meshes of the net. Above the mean the distribution probably represents fairly that of the fish on the sea bottom. But below the mean, the distribution represents mainly the action of the net.

It is evident also that no combination of nets will succeed in representing the general distribution of plaice on the sea bottom, when the lengths of the fish are below about 15 cms. We might use a shrimp-trawl (an half-inch mesh), and thus obtain such catches as are tabulated on p. 258, or a four-inch trawl mesh, when such catches as are tabulated on p. 102, in the Report for 1909, would be obtained.* But the curve obtained by plotting these figures would differ according to the share which the nets of $\frac{1}{2}$, 4, and 6-inch meshes had in obtaining the total catch, and we should not know what proportional numbers of hauls by each kind of net ought to be made. It is true that we should be able to determine the mode, since the position of this would gradually change as the absolute number of plaice below 17 cms. becomes greater, and, finally, would become stationary, but an infinite number of curves would obviously be obtained, differing in their parameters.

Much the same difficulties apply, of course, to the use of nets in obtaining samples of plankton. As the area of the mesh changes, the composition of the plankton will also change. A fine enough mesh will capture all, or most of the micro-plankton, but in proportion as the area diminishes, so the net will fail to capture the larger planktonic organisms, since these will be driven out again from the mouth of the net by the reflux of water from the latter, just as large plaice are seldom taken in a shrimp trawl even if they are present on the sea bottom. Only a net of the same length as the vertical column of

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* *Rept. Lancashire Sea-Fish. Laby.* for 1909, p. 102.

water which it is desired to investigate will capture all the organisms, great or small, present in this water, and the use of such a net is, of course, impracticable. Neither could we attempt successfully to obtain a representative sample of all the plankton organisms present by using a series of nets of different meshes, since, just as in the case of the trawl-nets, there is nothing to show how many hauls of each kind of net should be made so that approximately similar samples of all the kinds of organisms in the water might be obtained. The difficulty is, in fact, a much more serious one in the case of plankton fishing than in the case of trawling for the investigation of length frequencies in the fish population inhabiting the ground sampled; for the error involves the numbers of kinds, or species, actually present. It is impossible that any combination of ordinary nets can actually obtain a true sample of all the species present except by chance, while if the combination be changed, the relative numbers of the species obtained must also change.

The table on p. 269 giving the values of the coefficient k continues the investigations of former years. These figures have been calculated by equating the expression $\int_{L_2}^{L_1} ax^3dx$ to the sum of the average weights of the sample, the series being continuous between the limits L_1 and L_2. The method assumes that the function ax^3 represents the increase of weight with increasing length, x being the length, and a a constant. This relation is, as I showed in last year's report, not quite accurate, but the error involved by employing it is probably quite insignificant. The object in making these evaluations of the coefficient k was originally the determination of the differences in "condition" of plaice on different grounds; and it was assumed that k would be low on fishing grounds where the plaice were very abundant, that is, "overcrowded." I am not convinced now that there is any evidence in favour of the hypothesis that the condition, or rate of growth of plaice varies inversely with some function of their degree of aggregation on the sea bottom. The view depends on the analogy with human populations, where "overcrowding" is generally concomitant with poverty, and insufficient means of nutrition; or perhaps with the conditions which are said to obtain in a river "overstocked" with trout artificially hatched and reared. Before it can be applied to a population of fish in an open sea, or an estuarine area, some estimate of the degree of aggregation of the fish on the ground must be obtained; as well as estimates of the amount of food actually present. What we do know points to so great an abundance of the latter on the grounds much frequented by small plaice that it is difficult to imagine that food is deficient on these areas. In the few cases known to me where the sea bottom as well as the plaice living there have been sampled, the former reveals an extraordinary abundance of invertebrate life, being sometimes literally carpeted by small mussels, or *Scrobicularia* or *Pectinaria* or *Cardium*.

It is far more probable that variations in the value of the coefficient k are due to purely physical conditions. I have discussed this question, and the evidence bearing upon it in another paper in this report, and have suggested that the main cause of the periodic migrations made by plaice is change of temperature. The migration is of the nature of an adaptation to a change in the environment of the animal, and the latter responds by so moving that the temperature change becomes minimal. But the range of temperature, at the same time, on the grounds available to plaice is probably limited, since obviously plaice do not normally inhabit water of more than a limited depth, nor do they ascend rivers as a flounder does. Experiments carried out on a sufficiently big scale with the latter fish would probably show that its migrations are more clearly adaptations to changes of temperature than in the case of the plaice, since it is apparently able to inhabit water of a similar range of depths, and is, besides, able to live in water of a much greater range of salinity variation. Its possible change of habitat is, therefore, greater than that of the plaice.

The latter fish being unable, then, to remain in water of the same temperature (that is, being limited in its power of adaptation) must react to the change in this factor, and this it does by an obligatory change in its rate of metabolism. At a higher temperature, there must be greater tissue waste—we have experimental evidence that the respiratory movements, and the excretion of CO_2 are increased—and consequently greater tissue repair and assimilation. It is true that the intake and output of material might be equal, but it is hardly likely that this condition of nitrogenous equilibrium should obtain in the case of a growing plaice. In this fish, unlike the Clupeoids or Salmonids, there is apparently little change in the fat-content of the tissues. There are no actual determinations of this that I know of—an obvious gap in fishery investigation—but no visible change in fat content has been apparent in the numerous samples of plaice, taken from different fishing grounds, and at all times throughout the year. Change of temperature, therefore, is probably to be associated with change, in the same direction, of rate of metabolism, and change of increment of tissue formation, that is, with variations in the coefficient k, the latter being greater with temperatures above the mean, and less with temperatures below the mean.

These changes of the coefficient are more marked in the case of plaice below a certain size-limit—about 20 to 25 cms.—and these are also the plaice which do not migrate so regularly as those of sizes more nearly approximating to that at which sexual maturity is attained. They are, therefore, less able to maintain a certain degree of uniformity in their rate of metabolism by making migrations, than are the larger fishes.

It is true that the changes of temperature which can be observed, and correlated with these changes in the value of the coefficient are small ones. But it must be remembered that this effect of temperature is an integrative one. The change continues to be exerted for relatively considerable periods, and its effect is accumulated.

It must be admitted, however, that the fluctuations in the value of k recorded in this and previous papers, are not easily correlated with concomitant temperature changes. This imperfect correlation is, however, due to the imperfect data at our disposal: the samples of plaice examined are far too few, and the temperature data are also quite insufficient. Smoothed curves, drawn from monthly observations would probably not show the relationship sought. The temperature variations of the inshore waters of the coasts of Lancashire are certainly not to be represented by the simple harmonic expressions consisting of two or three terms only, which such smoothed curves represent. They are relatively complex, and probably incapable of any practicable harmonic analysis; and it would be results obtained by graphic integration of curves drawn empirically from numerous observations that would alone be susceptible of comparison with the changes of the coefficient k. The relation is only suggested here, since it is hopeless to attempt to demonstrate it by the data available.

So far, only plaice have been studied by the methods of this and the previous papers. There is no reason why other species inhabiting the Lancashire Fishery Area should not also be investigated in the same manner. But the difficulty of obtaining series of data, and results capable of exhibiting the relationships expected on *a priori* grounds, much less capable of withstanding statistical tests, is so great that only this fish has been examined. It may also be expected that the results obtained from the study of one species would possess a certain degree of generality, and that conclusions so obtained might be extended to other species. An indubitable numerical correlation between physical changes and plaice migrations, or rate of growth, or the value of the length-weight coefficient, or the incidence and duration of a spawning season, might also be expected to hold good with respect to other fishes, such as the sole. There would be some differences, of course, but these could be allowed for by investigation of these other species, on a scale of less magnitude than that applied to the plaice.

TABLES. I.—LENGTH FREQUENCIES.

	Luce Bay.				King William Bank.	10 m. W.N.W. Piel Gas Buoy.	Near Selker Ship.	Off St. Bees Head.
	22 Oct. 1912.		20 Nov. 1912.		Mar. 18.	Mar. 6.	June 6.	July 31.
	Total.	Mature Fish.	Total.	Mature Fish.				
10·5	—	—	1	—	—	—	—	—
11·5	2	—	1	—	—	—	—	—
12·5	3	—	—	—	—	—	—	—
13·5	3	—	—	—	—	—	—	—
14·5	4	—	2	—	—	—	1	—
15·5	13	—	5	—	1	—	6	—
16·5	19	—	6	—	1	—	17	2
17·5	41	—	8	—	3	—	38	4
18·5	60	—	16	—	1	—	52	6
19·5	82	—	26	—	1	1	57	4
20·5	76	—	27	—	1	1	30	6
21·5	84	—	28	—	1	1	19	4
22·5	66	—	40	—	1	2	16	7
23·5	77	—	57	—	—	3	11	4
24·5	42	—	38	—	2	—	3	—
25·5	36	—	34	—	2	4	8	2
26·5	46	1	38	—	1	—	4	5
27·5	38	—	36	—	1	4	3	—
28·5	35	2	31	—	2	2	1	1
29·5	34	1	38	—	2	2	—	1
30·5	20	3	32	—	1	1	1	1
31·5	30	8	28	1	1	—	—	—
32·5	29	14	26	2	—	—	—	—
33·5	39	25	42	6	1	—	—	1
34·5	32	27	34	13	—	—	—	—
35·5	23	20	41	24	1	—	—	1
36·5	21	20	27	16	1	—	—	—
37·5	19	19	30	25	—	—	—	—
38·5	20	20	24	21	1	—	—	—
39·5	9	9	21	21	—	—	—	—
40·5	16	16	11	11	1	—	—	—
41·5	5	5	7	7	—	—	—	—
42·5	8	8	5	5	1	—	—	—
43·5	7	7	4	4	1	—	—	—
44·5	4	4	3	3	—	—	—	—
45·5	5	5	1	1	—	—	—	—
46·5	4	4	2	2	—	—	—	—
47·5	2	2	3	3	—	—	—	—
48·5	1	1	3	3	1	—	—	—
49·5	1	1	1	1	—	—	—	—
50·5	—	—	—	—	—	—	—	—
51·5	2	2	—	—	—	—	—	—
52·5	2	2	1	1	—	—	—	—
53·5	2	2	1	1	—	—	—	—
54·5	1	1	—	—	—	—	—	—
55·5	—	—	—	—	—	—	—	—
56·5	1	1	—	—	—	—	—	—
57·5	1	1	—	—	—	—	—	—
58·5	2	2	—	—	—	—	—	—
59·5	—	—	—	—	—	—	—	—
60·5	—	—	—	—	—	—	—	—
61·5	—	—	—	—	—	—	—	—
62·5	1	1	—	—	—	—	—	—
Total	1068	234	779	171	30	21	267	49

S.S. "James Fletcher."

Off Duddon Banks.

	March.	April.	May.
10·5	—	—	—
11·5	1	—	—
12·5	—	1	1
13·5	1	7	1
14·5	4	20	3
15·5	9	67	29
16·5	21	45	60
17·5	9	52	77
18·5	5	26	47
19·5	6	31	34
20·5	6	11	39
21·5	3	14	28
22·5	4	11	40
23·5	3	12	46
24·5	1	6	33
25·5	—	4	11
26·5	1	1	15
27·5	—	1	6
28·5	—	2	8
29·5	—	1	3
30·5	—	1	1
31·5	—	—	1
32·5	—	—	—
33·5	—	—	—
34·5	—	—	—
35·5	—	—	—
36·5	—	—	—
37·5	—	—	—
38·5	—	—	—
39·5	—	—	—
40·5	—	—	—
	74	313	483

S.S. "James Fletcher."

Near Nelson Buoy; Off Blackpool.

	May.	June.	July.	Aug.	Sept.	Oct.
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	1	—	1	—	—	—
13·5	8	—	1	10	1	4
14·5	25	1	—	14	8	4
15·5	104	4	4	10	16	28
16·5	251	22	43	7	30	45
17·5	225	43	122	41	83	72
18·5	166	46	178	81	117	71
19·5	118	36	207	72	148	79
20·5	74	27	191	66	121	71
21·5	35	24	104	80	113	64
22·5	17	7	109	73	102	51
23·5	10	2	68	59	93	45
24·5	8	2	61	48	84	28
25·5	13	—	38	48	51	20
26·5	5	1	21	51	24	16
27·5	9	2	16	51	19	7
28·5	8	1	12	28	10	4
29·5	3	1	6	22	4	3
30·5	10	—	1	21	6	1
31·5	2	1	10	10	2	1
32·5	1	—	9	9	2	1
33·5	2	—	3	10	—	1
34·5	1	—	2	8	1	2
35·5	—	—	2	4	2	1
36·5	—	—	1	6	1	—
37·5	—	—	3	1	—	2
38·5	—	—	2	6	1	—
39·5	—	—	—	1	—	—
40·5	—	—	2	1	—	2
41·5	—	—	—	—	—	—
44·5	—	—	1	—	—	—
46·5	—	—	—	—	1	—
	1096	220	1218	838	1040	623

S.S. "James Fletcher."
3 hauls by police cutter "Piel Castle," Fleetwood Station.

	Near Liverpool Bar.			Horse Channel.						West Hoyle Bank.	
	July.	Aug.	Sept.	April.	June.	July.	Aug.	Sept.	Oct.	April.	May.
10·5	—	—	—	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—	—	—	—
12·5	2	2	—	—	—	1	—	—	—	—	—
13·5	16	9	—	2	1	4	—	1	—	10	1
14·5	48	17	2	—	—	14	—	2	—	12	5
15·5	128	65	6	2	1	63	1	3	3	13	3
16·5	174	121	18	9	12	125	7	10	6	18	1
17·5	145	98	11	11	15	139	11	14	27	16	4
18·5	124	99	25	10	23	152	12	15	47	8	11
19·5	78	64	18	10	26	164	12	22	89	5	10
20·5	80	70	30	3	11	117	15	32	37	1	7
21·5	51	53	35	7	5	99	15	28	58	9	7
22·5	39	34	28	18	5	56	9	21	38	8	7
23·5	27	43	22	8	1	19	8	21	19	10	6
24·5	6	13	18	9	1	11	3	17	22	5	7
25·5	6	7	18	5	3	7	1	12	4	13	8
26·5	3	4	19	—	—	1	3	12	5	11	6
27·5	4	3	14	—	—	—	1	8	2	20	12
28·5	2	2	6	—	—	—	—	5	2	10	10
29·5	3	2	8	—	2	1	—	7	—	4	5
30·5	3	1	5	—	1	—	—	9	1	5	10
31·5	—	3	4	—	1	—	—	4	—	4	10
32·5	—	1	4	—	1	3	—	—	—	1	3
33·5	2	1	8	—	1	1	—	1	—	4	2
34·5	2	—	1	—	1	2	—	3	—	1	—
35·5	1	1	4	—	—	2	—	1	1	3	—
36·5	1	1	—	—	—	2	—	—	1	—	—
37·5	1	—	2	—	—	1	—	—	—	1	—
38·5	2	—	—	—	—	1	—	1	—	—	—
39·5	—	1	1	—	—	—	—	—	—	—	—
40·5	—	—	—	—	—	—	—	—	—	—	—
53·5	—	1	—	—	—	—	—	—	—	—	—
	948	716	307	94	111	985	98	249	362	192	135

Police cutter "John Fell," New Brighton Station. Four hauls by S.S. "James Fletcher."

Mersey Estuary, half-inch trawl mesh.

	Rock Channel.	Horse Channel.	Rock Channel.	Horse Channel.	Rock Ch. Crosby Ch. Burbo Bk.	Rock Channel.	Rock Channel.	Horse Channel.
	January.	January.	February.	March.	March.	October.	November.	December.
4·5	38	—	—	14	20	8	5	4
5·5	362	67	—	108	51	76	46	25
6·5	643	55	2	324	50	101	47	56
7·5	1598	176	14	864	248	56	60	37
8·5	875	363	38	648	544	36	62	31
9·5	224	44	13	304	112	82	46	32
10·5	94	15	11	39	26	263	71	49
11·5	27	66	18	34	77	365	41	29
12·5	11	22	17	29	111	370	15	3
13·5	21	11	15	—	67	421	3	2
14·5	5	3	15	—	25	278	4	2
15·5	3	—	19	—	51	187	—	1
16·5	1	—	10	—	61	80	1	—
17·5	2	—	5	—	33	23	—	—
18·5	—	—	5	—	14	7	—	—
19·5	—	—	—	—	16	1	—	—
20·5	—	—	3	—	4	1	—	—
21·5	—	—	1	—	5	3	—	—
22·5	—	—	3	—	1	2	—	—
23·5	—	—	—	—	2	—	—	—
24·5	—	—	—	—	2	1	—	—
25·5	—	—	1	—	2	—	—	—
26·5	—	—	—	—	—	—	—	—
27·5	—	—	2	—	—	—	—	—
	3904	822	192	2364	1522	2361	401	271

Police cutter "John Fell," New Brighton Station.

Red Wharf, Beaumaris, Conway and Colwyn Bays.

	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
10·5	—	—	—	—	—	—	—	—
11·5	—	—	—	—	1	—	—	—
12·5	—	—	—	—	2	1	—	—
13·5	—	1	—	—	1	6	—	—
14·5	1	2	—	—	3	48	3	—
15·5	4	16	1	5	12	323	28	2
16·5	11	48	1	19	18	936	65	7
17·5	14	52	6	110	22	1065	75	31
18·5	10	58	13	147	25	751	43	82
19·5	7	35	17	195	19	478	32	80
20·5	3	33	18	147	12	334	21	92
21·5	1	22	17	136	15	272	14	59
22·5	1	14	12	88	8	200	15	69
23·5	2	15	9	56	6	113	6	58
24·5	—	9	4	52	8	92	9	34
25·5	—	8	6	29	7	74	2	27
26·5	2	3	—	18	3	65	1	28
27·5	—	4	2	14	7	42	3	14
28·5	2	6	3	12	2	44	2	13
29·5	—	4	2	15	3	30	3	7
30·5	—	2	3	13	1	18	3	11
31·5	—	4	—	8	1	12	2	6
32·5	1	1	1	9	1	15	—	6
33·5	—	1	1	3	—	11	—	5
34·5	—	1	—	2	—	5	—	6
35·5	—	—	—	1	1	7	—	1
36·5	1	1	—	2	—	3	—	—
37·5	—	—	—	—	—	1	2	3
38·5	—	—	—	1	—	2	—	4
39·5	—	—	—	1	—	1	—	—
40·5	—	—	—	1	—	1	—	2
41·5	—	—	—	—	—	3	—	
42·5	—	—	—	—	—	—	—	—
43·5	—	—	—	—	—	2	—	—
44·5	—	—	—	—	—	—	—	—
45·5	—	—	—	—	—	—	—	—
46·5	—	—	—	—	—	—	1	—
47·5	—	—	—	—	—	—	—	1
48·5	—	—	—	—	—	—	—	1
49·5	—	—	—	—	—	—	—	1
50·5	—	—	—	—	—	—	—	—
	60	340	116	1084	178	4955	330	650

S.S. "James Fletcher."

Menai Straits.

	Jan.	Feb.	Mar.	April	Aug.	Nov.	Dec.
14·5	—	—	—	1	—	5	—
15·5	—	1	3	1	—	3	—
16·5	—	3	1	6	—	8	10
17·5	5	7	4	2	5	28	22
18·5	9	3	4	6	6	20	28
19·5	8	8	5	6	8	44	32
20·5	9	4	6	2	5	54	30
21·5	10	4	1	2	2	21	16
22·5	3	4	1	2	5	20	13
23·5	1	4	—	2	2	12	13
24·5	2	3	—	1	6	12	5
25·5	2	2	1	—	1	4	4
26·5	—	1	—	—	3	3	4
27·5	5	1	—	—	4	—	—
28·5	3	—	—	1	4	—	—
29·5	1	—	—	—	5	—	—
30·5	2	1	—	—	1	—	3
31·5	—	—	—	—	5	—	—
32·5	1	—	—	—	—	—	1
33·5	—	—	1	—	3	—	—
34·5	1	—	—	—	4	—	1
35·5	—	—	—	—	5	—	1
36·5	—	—	—	—	7	—	—
37·5	1	—	—	—	—	—	—
38·5	—	—	—	—	3	—	—
39·5	—	—	—	—	1	—	—
40·5	1	—	—	—	4	—	—
41·5	—	—	—	—	1	—	—
42·5	—	—	—	—	—	—	—
43·5	—	—	—	—	5	—	—
44·5	—	—	—	—	—	—	—
45·5	—	1	—	—	2	—	—
46·5	—	—	—	—	—	—	1
47·5	—	—	—	—	—	—	—
48·5	—	—	—	—	1	—	—
49·5	—	—	—	—	—	—	—
50·5	—	—	1	—	—	—	—
	64	47	28	32	98	234	184

Police cutter "Eric," Carnarvon Station.

Carnarvon Bay.

	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	July.*
10·5	—	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—	—
12·5	—	—	—	—	—	—	—	—	—
13·5	—	—	—	—	—	—	—	—	—
14·5	—	—	—	—	—	—	—	—	—
15·5	—	—	4	—	1	—	—	—	—
16·5	—	—	4	1	1	10	—	—	—
17·5	—	—	3	—	5	22	4	—	7
18·5	—	—	—	—	3	34	9	2	25
19·5	—	—	—	2	6	25	11	—	38
20·5	—	2	1	5	6	18	9	1	32
21·5	—	1	1	2	4	10	10	—	45
22·5	—	—	1	—	4	5	6	3	41
23·5	1	—	—	1	3	3	7	—	32
24·5	1	—	—	2	2	2	3	2	18
25·5	1	—	—	1	—	3	1	—	16
26·5	—	—	1	—	—	3	—	—	12
27·5	—	3	1	1	1	—	—	—	10
28·5	—	—	1	1	—	—	1	—	8
29·5	—	—	—	1	—	—	—	—	3
30·5	1	1	1	1	—	—	—	—	3
31·5	—	—	—	1	—	—	—	—	3
32·5	—	—	—	—	—	—	—	—	—
33·5	—	—	—	1	—	—	—	—	—
34·5	—	—	—	—	—	—	—	—	—
35·5	—	—	—	1	—	—	—	—	—
36·5	—	—	—	1	—	—	—	—	—
37·5	—	—	—	—	—	—	—	—	—
38·5	—	—	—	—	—	—	—	—	—
39·5	—	—	—	—	—	—	—	—	—
40·5	—	—	—	—	—	—	—	—	—
41·5	—	—	—	—	—	—	—	—	—
	4	7	18	22	36	135	61	8	293

Police cutter "Eric," Carnarvon Station. * S.S. "James Fletcher."

	Tremadoc Bay.								**Near New Quay.**	
	Mar.	April.	June.	July.	Aug.	Sept.	Oct.	Nov.	Feb.*	July.*
12·5	—	17	—	—	—	—	—	—	—	—
13·5	—	24	—	—	—	—	—	—	—	—
14·5	—	21	—	—	—	—	—	—	—	—
15·5	—	24	—	—	—	—	—	—	—	—
16·5	—	14	—	—	—	—	—	—	1	—
17·5	—	19	—	—	—	—	—	—	1	1
18·5	—	13	—	—	—	—	—	—	1	3
19·5	—	14	—	—	—	—	—	—	—	4
20·5	—	18	3	—	—	—	—	—	3	9
21·5	—	8	4	—	—	—	—	—	2	7
22·5	2	1	2	—	—	—	—	—	5	16
23·5	2	6	1	—	—	—	—	1	2	9
24·5	—	3	2	—	—	—	—	1	4	11
25·5	—	3	—	3	—	—	2	—	6	13
26·5	—	5	—	2	—	—	3	—	5	20
27·5	—	2	—	3	1	4	—	—	5	18
28·5	—	29	—	4	—	—	4	—	6	24
29·5	—	9	—	—	2	2	1	1	13	27
30·5	—	14	—	1	3	—	—	—	8	25
31·5	—	16	—	—	—	3	—	—	10	19
32·5	—	9	—	1	—	—	—	—	6	12
33·5	—	9	—	—	—	—	—	—	5	7
34·5	—	3	—	—	—	—	—	—	4	2
35·5	—	7	—	—	—	—	—	—	6	2
36·5	—	3	—	—	—	—	—	—	3	—
37·5	—	2	—	—	—	—	—	—	1	1
38·5	—	3	—	—	—	1	—	—	1	2
39·5	—	—	—	—	—	1	—	—	1	—
40·5	—	—	—	—	—	—	—	—	—	—
41·5	—	—	—	—	—	—	—	—	3	—
42·5	—	—	—	—	—	—	—	—	1	—
43·5	—	—	—	—	—	—	—	—	1	—
44·5	—	—	—	—	—	—	—	—	—	—
45·5	—	—	—	—	—	—	—	—	1	—
46·5	—	1	—	—	—	—	—	—	1	—
47·5	—	—	—	—	—	—	—	—	—	—
48·5	—	—	—	—	—	—	—	—	—	—
	4	297	12	14	6	11	10	3	106	232

Police cutter, Pwllheli Station. * S.S. "James Fletcher."

II.—LENGTH, SEX AND AGE.

Age Groups: Near Nelson Buoy; Blackpool Closed Ground, 1912.

	May, 1912.								June, 1912.								July 1912.								August, 1912.								September 1912.								October, 1912.							
Sex.	♂				♀				♂				♀				♂				♀				♂				♀				♂				♀				♂				♀			
Group.	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
10·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...
14·5	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...
15·5	2	2	...	...	1	4	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	3	...	...	...	7	...	...	...	5	...	...	...
16·5	1	8	...	...	...	8	1	...	2	...	...	...	5	...	...	...	...	1	...	...	...	...	...	...	1	...	...	...	3	...	...	...	...	...	...	...	...	2	...	...	5	2	...	...	4	2	...	...
17·5	1	10	...	...	1	11	...	...	6	1	...	...	8	3	...	...	...	6	...	...	1	1	...	...	7	1	...	...	2	1	...	...	1	3	...	...	...	4	...	...	5	5	...	...	1	1	...	...
18·5	...	7	...	...	1	3	...	...	7	2	...	...	3	4	...	...	4	8	...	...	2	5	...	...	6	1	...	...	4	2	...	...	...	6	...	...	...	5	...	...	5	17	...	...	2	8	...	...
19·5	...	8	...	...	...	8	...	...	1	3	...	...	5	5	...	...	4	11	...	...	...	4	...	...	...	5	...	...	1	4	...	...	...	8	...	...	...	6	...	...	2	10	...	...	1	9	...	...
20·5	1	1	...	...	...	4	...	...	1	6	2	...	...	6	2	...	...	9	1	...	...	6	...	...	...	6	...	...	...	6	...	...	...	9	...	...	...	12	...	...	1	16	...	...	...	13	1	...
21·5	1	...	...	...	2	4	...	...	...	13	...	...	...	4	2	...	...	5	...	...	...	6	1	...	...	8	...	...	...	11	...	...	...	1	1	...	...	5	2	...	...	10	...	...	...	10	...	...
22·5	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	2	...	...	2	...	...	...	5	...	...	...	3	...	...	...	3	2	...	...	1	2	...	...	7	...	...	...	7	...	...
23·5	...	...	...	...	...	1	...	...	...	...	1	...	...	...	...	...	...	4	2	...	...	1	...	...	...	2	...	...	...	1	1	...	...	3	5	...	...	2	2	...	...	9	...	...	...	6	...	...
24·5	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	1	2	...	...	...	...	...	...	2	...	...	...	...	1	...	...	1	1	...	...	2	...	...	...	7	...	...
25·5	...	1	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	1	1	...	...	...	1	...	...	1	...	...	...	...	1	...	...	...	3	...	...	3	...	...	...	2	...	...
26·5	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	1	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	3	...	...
27·5	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	3	1	...	...	1	...	...
28·5	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	1	...	...
29·5	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30·5	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
31·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
32·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
33·5	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...
35·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...
38·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
40·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Mersey Estuary, 1912.

Date.	July, 1912.								October, 1912.								Oct., 1912.			Nov., 1912.		
Sex.	♂				♀				♂				♀				♂ ♀			♂ ♀		
Group.	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	0	1	2	0	1	2
6·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	11	…	…	…	…	…
7·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	7	…	…	…	…	…
8·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	2	1	…	…	…	…
9·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	13	…	2	…	…
10·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	3	…	…	7	…
11·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	12	…	…	5	…
12·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	12	…	…	4	…
13·5	…	…	…	…	2	…	…	…	…	…	…	…	…	…	…	…	…	12	…	…	4	…
14·5	…	…	…	…	…	…	…	…	1	…	…	…	…	…	…	…	…	18	…	…	2	…
15·5	3	…	…	…	2	…	…	…	1	…	…	…	6	…	…	…	…	22	2	…	3	…
16·5	2	5	…	…	6	3	…	…	10	1	…	…	11	1	…	…	…	9	…	…	3	…
17·5	4	1	…	…	2	3	…	…	5	1	…	…	8	1	…	…	…	…	…	…	…	…
18·5	1	1	…	…	3	1	…	…	10	3	…	…	6	1	…	…	…	…	…	…	…	…
19·5	…	7	…	…	3	6	…	…	8	3	…	…	4	2	…	…	…	…	…	…	…	…
20·5	1	4	…	…	…	5	…	…	4	5	…	…	7	4	…	…	…	…	…	…	…	…
21·5	…	1	…	…	…	2	…	…	…	1	1	…	…	1	…	…	…	…	…	…	…	…
22·5	…	2	1	…	…	4	1	…	…	1	…	…	…	4	…	…	…	…	…	…	…	…
23·5	…	1	…	…	…	…	…	…	…	4	…	…	…	1	…	…	…	…	…	…	…	…
24·5	…	…	…	…	…	3	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
25·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
26·5	…	…	…	…	…	…	…	…	…	1	…	…	…	…	…	…	…	…	…	…	…	…
27·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
28·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
29·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	1	…	…	…	…	…	…	…
30·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
31·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
32·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
33·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
34·5	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
35·5	…	…	1	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Red Wharf Bay, Beaumaris Bay, Conway Bay, Colwyn Bay, 1912.

Date.	June, 1912.						July, 1912.								Aug., 1912.						Sept., 1912.							October, 1912.								Nov., 1912.							December, 1912.							
Sex.	♂			♀			♂				♀				♂			♀			♂				♀			♂				♀				♂				♀			♂				♀			
Group.	1	2	3	1	2	3	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4
10·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14·5	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	...	...	2	...	...	...	1	...	...	...	2	...	...	...	1	...	...	...	...	...	...	...	...	...	...
15·5	...	6	...	...	1	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	4	...	...	...	2	1	...	2	1	...	...	1	...	...	...	7	...	...	...	6	1	...	...	...	...	...	...	...	...	...
16·5	...	6	...	...	8	...	1	2	...	...	1	2	...	...	...	3	...	...	...	...	2	2	...	...	3	1	...	13	5	...	...	7	4	...	...	14	1	...	...	18	...	...	...	...	...	...	...	...	...	...
17·5	1	15	...	...	9	...	5	7	...	...	1	2	...	...	1	5	...	1	5	...	2	2	...	...	3	2	...	13	11	...	...	11	7	...	...	14	3	...	...	8	1	...	...	...	...	...	2	1	...	...
18·5	1	9	...	...	8	...	4	11	...	...	4	8	...	...	...	8	...	...	9	...	4	3	...	...	3	7	...	5	14	...	...	6	19	...	...	2	4	...	...	2	9	...	3	3	...	...	2	3	...	...
19·5	1	6	...	...	3	...	...	13	...	...	...	8	1	...	...	9	...	...	6	...	...	5	...	...	...	3	...	3	17	...	...	6	19	...	...	...	8	...	...	1	16	...	1	4	...	...	2	8	...	...
20·5	...	1	3	...	5	...	...	12	3	...	...	14	4	...	...	9	2	...	5	1	...	7	...	...	...	2	...	3	9	...	...	...	5	...	...	...	7	...	...	...	5	...	...	11	...	...	...	9	...	...
21·5	...	3	...	...	2	...	...	11	2	...	...	12	5	...	...	6	2	...	3	...	...	6	...	...	...	3	...	...	9	...	...	...	12	...	...	...	10	...	...	...	9	1	...	9	...	...	...	3	...	...
22·5	...	1	1	...	2	1	...	4	3	...	...	2	5	...	...	2	...	...	2	...	...	3	...	...	...	2	...	...	11	...	...	...	15	1	...	...	8	...	...	...	5	1	...	6	...	...	...	10	1	...
23·5	...	...	...	...	...	2	...	3	5	...	...	2	2	...	...	1	...	...	2	2	...	1	...	...	...	2	...	...	5	...	...	...	5	...	...	...	2	...	...	...	6	...	...	2	1	...	...	5	...	...
24·5	...	...	...	...	...	2	...	...	3	...	...	2	4	...	...	1	1	...	...	...	...	2	2	...	...	3	...	...	2	2	...	...	3	3	...	...	...	2	...	...	3	2	...	2	...	...	...	2	...	...
25·5	...	...	...	...	...	...	...	...	2	...	...	...	1	...	...	...	1	...	...	1	...	...	1	...	...	...	...	...	5	3	...	...	6	2	...	...	1	2	...	...	...	...	...	1	2	...	...	1	...	...
26·5	...	...	...	...	...	...	...	...	1	...	...	...	3	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	2	1	...	...	3	2	...	...	1	1	...	...	1	...	...	...	...	1	...	2	...	...
27·5	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	2	...	...	1	...	...	...	...	...	...	5	...	...	2	...	...	1	3	1	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...
28·5	...	...	...	...	...	...	...	1	1	...	...	...	3	...	...	...	1	...	...	1	...	...	...	...	...	...	1	...	...	3	...	...	...	1	1	...	...	3	...	...	...	1	...	...	...	...	...	...	...	...
29·5	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	3	...	...	...	1	...	...	...	1	...	...	...	...
30·5	...	...	...	...	...	1	...	...	...	...	...	...	1	...	...	...	3	...	...	1	...	...	2	...	...	...	1	...	...	1	2	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...
31·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...
32·5	...	...	...	...	...	...	...	...	...	...	...	...	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
33·5	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
35·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	2	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37·5	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
38·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
40·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Cardigan and Carnarvon Bays, 1912.

Date.	Near New Quay, July, 1912.								Carnarvon Bay, May, 1912.						Carnarvon Bay, June, 1912.						Carnarvon Bay, July, 1912.							Menai Straits, May, 1912.							Menai Straits, Nov., 1912.						Menai Straits, Dec., 1912.							
Sex.	♂					♀			♂			♀			♂			♀			♂			♀				♂				♀			♂			♀			♂				♀			
Group.	1	2	3	4	5	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	4	1	2	3	4
10·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	5	3	...	...	1	...	...	...	3	...	...	...	3	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
17·5	...	3	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	...	...	1	4	8	...	3	6	...	...	...	3	1	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
18·5	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	1	...	7	13	...	3	10	...	...	...	2	...	...	...	2	2	3	3	...	...	2	...	...	...	...	...	...	...	...	...
19·5	...	2	...	...	...	2	...	...	...	1	...	...	3	...	...	2	2	...	1	...	...	8	...	...	5	3	...	...	...	...	...	...	2	1	1	4	...	1	5	...	...	...	...	...	2	1	...	...
20·5	...	8	...	...	...	3	...	...	...	...	...	...	1	...	...	...	2	...	...	3	...	4	...	...	5	...	...	...	...	1	...	...	...	...	2	1	1	...	6	1	...	1	...	...	...	5	...	...
21·5	...	4	2	...	...	2	...	...	...	1	...	...	...	...	...	...	2	...	1	1	...	1	1	...	3	3	...	...	1	...	...	...	2	...	...	2	...	2	3	...	...	1	...	...	...	3	...	...
22·5	...	6	3	...	...	3	3	...	...	...	...	...	...	...	...	...	3	...	1	...	...	...	2	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	2	...	...	3	...	...	...	2	...	...
23·5	...	2	2	1	...	3	1	...	...	...	...	...	...	...	...	...	3	...	...	1	...	...	1	...	...	1	...	...	...	1	...	...	...	...	...	...	2	...	1	1	...	2	...	...	...	1	...	...
24·5	...	3	3	...	...	...	...	...	...	...	1	...	...	...	...	...	1	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
25·5	...	4	2	...	...	...	1	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	1	...	...	...	1	...	...
26·5	...	3	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...
27·5	...	...	5	...	...	1	1	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	1	...	...	...	...	...	...	...	...
28·5	...	...	5	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29·5	...	...	3	2	...	...	1	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30·5	...	...	1	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...
31·5	...	...	1	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
32·5	...	...	...	1	1	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
33·5	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
35·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
38·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
40·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Sex and age of 4,054 Plaice captured during the months October to March, 1909-1912; Anglesey to Cumberland.

Sex	Male.				Female.			
Age Group	I.	II.	III.	IV.	I.	II.	III.	IV.
Mean length.								
9·5	2	—	—	—	—	—	—	—
10·5	1	—	—	—	5	—	—	—
11·5	3	—	—	—	7	—	—	—
12·5	13	—	—	—	6	—	—	—
13·5	11	—	—	—	12	—	—	—
14·5	26	2	—	—	18	1	—	—
15·5	69	16	—	—	64	15	—	—
16·5	149	57	—	—	142	43	—	—
17·5	178	133	—	—	142	81	—	—
18·5	161	147	2	—	127	144	1	—
19·5	99	125	7	—	72	146	12	—
20·5	56	125	6	—	51	117	11	—
21·5	28	115	10	—	21	126	11	—
22·5	9	88	4	—	17	109	14	—
23·5	9	75	10	—	15	81	7	—
24·5	5	50	10	—	8	64	14	—
25·5	1	41	16	1	3	50	7	—
26·5	—	36	11	1	1	29	12	—
27·5	—	39	14	—	2	17	14	—
28·5	—	13	13	2	1	12	13	—
29·5	—	9	9	5	4	10	18	1
30·5	—	2	13	5	3	7	9	—
31·5	—	3	5	2	1	7	11	2
32·5	—	3	8	1	—	2	11	—
33·5	—	—	3	—	—	1	3	2
34·5	—	2	2	4	—	—	6	4
35·5	—	—	2	4	—	—	—	3
36·5	—	—	—	—	—	—	2	1
37·5	—	—	—	1	—	—	1	—
38·5	—	—	1	1	—	—	2	1
39·6	—	—	—	—	—	—	—	1
40·5	—	—	—	—	—	—	—	—
41·5	—	—	—	—	—	—	—	2
	820	1,081	146	27	722	1,062	179	17

Lengths and Ages of 4,348 Plaice, irrespective of sex, captured during the months October to March, 1909-1912, Anglesey to Cumberland.

Age Group	0	I.	II.	III.	IV.
Mean length.	No.	No.	No.	No.	No.
5·5	9	—	—	—	—
6·5	47	—	—	—	—
7·5	60	—	—	—	—
8·5	44	1	—	—	—
9·5	6	22	—	—	—
10·5	2	14	—	—	—
11·5	—	26	—	—	—
12·5	—	35	—	—	—
13·5	—	37	—	—	—
14·5	—	61	3	—	—
15·5	—	158	31	—	—
16·5	—	300	100	—	—
17·5	—	320	214	—	—
18·5	—	288	291	3	—
19·5	—	171	271	19	—
20·5	—	107	242	17	—
21·5	—	49	241	21	—
22·5	—	26	197	18	—
23·5	—	24	156	17	—
24·5	—	13	114	24	—
25·5	—	4	91	23	1
26·5	—	1	65	23	1
27·5	—	2	56	28	—
28·5	—	1	25	26	2
29·5	—	4	19	27	6
30·5	—	3	9	22	5
31·5	—	1	10	16	4
32·5	—	—	5	19	1
33·5	—	—	1	6	2
34·5	—	—	2	8	8
35·5	—	—	—	2	7
36·5	—	—	—	2	1
37·5	—	—	—	1	1
38·5	—	—	—	3	2
39·5	—	—	—	—	1
40·5	—	—	—	—	—
41·5	—	—	—	—	2
	168	1,668	2,143	325	44

III.—Average Values of the Co-efficient *k* during the years 1911 and 1912.

Fishing Ground.		Barrow Channel.	Nelson Buoy and Off Blackpool.	Mersey Estuary.	Red Wharf Bay Area	Menai Straits.	Carnarvon Bay.	Cardigan Bay.
1911	Jan.	0·964	—	—	—	0·971	—	—
	Feb.	—	—	—	—	—	—	—
	Mar.	—	—	0·834	—	—	—	—
	April	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—
	June	—	—	—	—	—	—	—
	July	—	0·974	1·15	0·918	—	—	—
	Aug.	—	0·991	1·14	0·996	—	—	—
	Sept.	1·06	1·06	—	1·04	—	—	—
	Oct.	1·04	—	—	1·11	—	—	—
	Nov.	—	—	—	1·05	—	—	—
	Dec.	—	—	—	1·01	—	—	—
1912	Jan.	—	—	—	—	—	—	—
	Feb.	—	—	—	—	—	—	—
	Mar.	—	—	—	—	—	—	—
	April	—	—	—	—	—	—	—
	May	—	0·981	—	—	1·45	1·06	—
	June	—	1·03	—	0·992	—	0·991	—
	July	—	1·03	0·995	1·03	—	1·00	0·987
	Aug.	—	1·05	—	1·03	—	—	—
	Sept.	—	0·997	—	1·00	—	—	—
	Oct.	—	1·06	0·812	1·03	—	—	—
	Nov.	—	—	—	0·958	0·921	—	—
	Dec.	—	—	—	0·924	0·800	—	—

EXPERIMENTS WITH MARKED PLAICE DURING 1912.

By Jas. Johnstone, B.Sc.

Three experiments were made in 1912. The first one dealt with 212 plaice, which were caught in the neighbourhood of Nelson Buoy on 5th June, and were liberated on the same date. At the end of the year 26 of these fishes had been returned.

The second experiment was made on 3rd October, when 153 plaice were caught and liberated, also in the neighbourhood of Nelson Buoy. At the end of the year 26 of these plaice had also been returned.

The third experiment was made in Luce Bay on 22nd October. At the end of a day's trawling for spawning plaice for Piel and Port Erin Hatcheries about 45 of the smaller plaice caught were marked and liberated. At the end of the year only one of these fish had been returned.

It is, of course, too soon to attempt to summarise the results of these experiments, since the fish marked will continue to be returned for another year. The migrations made are, however, charted on pp. 303-5, and are there discussed in relation to the movements of plaice in general which accompany changes of sea-temperature. Tables showing the details of the recaptures for the year 1912 are given here.

Experiment I, 1912.

No. of Label.	Length when Liberated in cms.	Place of Recapture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Capture.
LA 155	26·5	Morecambe Bay, 14 fathoms	53° 57′ N. 3° 38′ W.	9.6.12	26·5	0	1T
LA 280	22	N.W. from Nelson Buoy, 9 fathoms	53° 46′ N. 3° 20′ W.	12.6.12	22	0	2T
LA 253	21·5	Outside Nelson Buoy	53° 42′ N. 3° 21′ W.	13.6.12	—	—	2T
LA 282	23	20 miles W. of Blackpool	53° 43′ N. 3° 34′ W.	24.6.12	23·5	½	1T
LA 166	24	20 miles W. of Blackpool	53° 35′ N. 3° 44′ W.	25.6.12	24·5	½	1T
LA 244	21	20 miles W. of Blackpool	53° 36′ N. 3° 44′ W.	25.6.12	21	0	1T
LA 150	29·5	Morecambe Bay, 17 fathoms	53° 51′ N. 3° 38′ W.	25.6.12	30	½	1T
LA 258	31	14 miles N. from Liverpool Bar, 16 fathoms	53° 45′ N. 3° 23′ W.	28.6.12	31·5	½	1T
LA 274	21·5	8 miles W. of Morecambe Bay Lightship	53° 52′ N. 3° 43′ W.	8.7.12	23	1½	1T
LA 260	20	W. from Blackpool, 19½ fathoms	53° 43′ N. 3° 32′ W.	13.7.12	22·5	2½	1T
LA 269	28	N.W. from Liverpool Bar Lightship, 19 fathoms	53° 39′ N. 3° 43′ W.	15.7.12	29·5	1½	1T
LA 235	33	½ mile N.W. from Nelson Buoy	53° 43′ N. 3° 13′ W.	23.7.12	—	—	2T
LA 270	20	5 miles N.W. from Nelson Buoy, 11 fathoms	53° 45′ N. 3° 20′ W.	2.8.12	22	2	1T
LA 286	21	10 miles off Bar Lightship bearing S., 16 fathoms	53° 41′ N. 3° 20′ W.	8.8.12	24·5	3½	1T

EXPERIMENT I, 1912—*Continued*

No. of Label.	Length when Liberated in cms.	Place of Recapture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Capture.
LA 193	26	2 miles E.S.E. Bar Lightship, 10 fathoms (? ship bearing 2 miles E.S.E.)	53° 32′ N. 3° 20′ W.	9.8.12	27·5	1½	1T
LA 195	21	Nelson Buoy, 8 fathoms	53° 43′ N. 3° 19′ W.	12.8.12	23·5	2½	1T
LA 272	21	Abreast of Blackpool, 16 fathoms	53° 51′ N. 3° 34′ W.	13.8.12	24	3	1T
LA 271	21	4 miles N.E. from Morecambe Bay Lightship	53° 58′ N. 3° 28′ W.	19.8.12	22	1	1T
LA 246	22	Liverpool Bay, Blackpool Tower bearing E., 15 fathoms	53° 44′ N. 3° 29′ W.	4.9.12	25	3	1T
LA 242	28	8 miles N.W. Bar Lightship, 14 fathoms	53° 35′ N. 3° 27′ W.	11.9.12	31·5	3½	1T
LA 251	21·5	20 miles W. of Blackpool	53° 42′ N. 3° 36′ W.	14.9.12	25	3½	1T
LA 285	20·5	Off West Constable Buoy, 15 fathoms	53° 26′ N. 3° 50′ W.	22.9.12	23	2½	1T
LA 243	23·5	Between Liverpool N.W. Lightship and Liverpool Bar Lightship, 8 fathoms, L.W.	53° 31′ N. 3° 22′ W.	28.10.12	27	3½	1T
LA 268	29	Great Orme's Head	53° 22′ N. 3° 52′ W.	20.11.12	34	5	1T
LA 236	20	N.W. by N. off Great Orme's Head, 15 fathoms ...	53° 25′ N. 4° 3′ W.	23.11.12	25	5	ST
LA 128	28·5	Off Great Orme's Head, 13 fathoms	53° 25′ N. 3° 55′ W.	9.12.12	32·5	4	1T
LA 240	24·5	5 miles S.E. of Bahama Lightship	54° 18′ N. 4° 3′ W.	7.1.13	27·5	3	ST
LA 239	29	10 miles S.S.E. Bahama Lightship, 12 fathoms	54° 13′ N. 4° 2′ W.	13.1.13	37	8	ST

EXPERIMENT II, 1912.

No. of Label.	Length when Liberated in cms.	Place of Recapture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Capture.
LA 450	22	Half way between Nelson Buoy and Blackpool, 6 fathoms	53° 46′ N. 3° 8′ W.	5.10.12	22	0	2T
LA 362	29	2 miles N.E. from Nelson Buoy, 6 fathoms	53° 44′ N. 3° 10′ W.	5.10.12	29	0	2T
LA 338	24	Off Blackpool, 8 fathoms	53° 49′ N. 3° 22′ W.	9.10.12	24	0	2T
LA 341	24	S. side of Blackpool closed ground	53° 47′ N. 3° 6′ W.	9.10.12	24	0	2T
LA 298	20·5	½ mile below Lytham Pier	53° 44′ N. 3° 00′ W.	21.10.12	21	½	—
LA 311	21·5	Morecambe Bay, 9 fathoms	53° 59′ N. 3° 24′ W.	26.10.12	21·5	0	1T
LA 422	21·5	" Heading " Bog Hole, Southport, ½ mile N. from Southport Pier, L.W.	53° 40′ N. 3° 1′ W.	14.11.12	22	½	1T
LA 351	25	Great Orme's Head bearing S.E. by E., Point Lynus N.W.	53° 25′ N. 3° 58′ W.	19.11.12	25·5	½	2T
LA 313	25	Pinfold Channel, Ribble	53° 42′ N. 3° 1′ W.	19.11.12	25·5	½	2T
LA 373	21	Ulverston Channel	54° 7′ N. 3° 3′ W.	20.11.12	21	0	2T
LA 369	22	Off Puffin Island (island bearing S.)	53° 25′ N. 4° 2′ W.	20.11.12	23	1	1T
LA 334	25	Off Puffin Island (island bearing S.)	53° 25′ N. 4° 5′ W.	20.11.12	25·5	½	1T
LA 438	19	Wallasey shore in " hand net "	53° 25′ N. 3° 8′ W.	23.11.12	19	0	—
LA 318	21	Garston Deep	53° 19′ N. 2° 51′ W.	23.11.12	21·5	½	2T
LA 305	19	Horse Banks, off Ribble Estuary, stake-net	53° 42′ N. 3° 3′ W.	25.11.12	19	0	SN
LA 396	23	Horse Bank, Southport	53° 43′ N. 3° 4′ W.	27.11.12	23·5	½	—

EXPERIMENT II, 1912—*Continued*

No. of Label.	Length when Liberated in cms.	Place of Recapture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Capture.
LA 430	21	Bolton-le-Sands, in stake-net	54° 7′ N. 20° 48′ W.	29.11.12	—	—	SN
LA 316	25	North part of Cardigan Bay, 30 fathoms	—	29.11.12	25	0	ST
LA 306	23·5	Puffin Island, 14 fathoms	53° 24′ N. 4° 2′ W.	30.11.12	24	½	1T
LA 345	24	Off Puffin Island, 15 fathoms	53° 26′ N. 4° 1′ W.	30.11.12	24·5	½	1T
LA 403	22·5	5 miles N.W. by N. from Great Orme's Head	53° 23′ N. 3° 59′ W.	3.12.12	23	½	ST
LA 446	26·5	10 miles N. of the Orme's Head, 20 fathoms	53° 30′ N. 3° 58′ W.	8.12.12	27	½	ST
LA 327	25	Off Puffin Island, light bearing between S.S.W. and S.W., 18 fathoms	53° 26′ N. 3° 59′ W.	16.12.12	25·5	½	1T
LA 337	23	5 miles S. from Maughold Head	54° 13′ N. 4° 15′ W.	16.12.12	23	0	ST
LA 421	19·5	Near Annan, Waterfoot, Solway	54° 58′ N. 3° 15′ W.	16.12.12	20	½	—
LA 382	26·5	Near Baycliff	54° 6′ N. 3° 4′ W.	20.12.12	26·5	0	—

EXPERIMENT III, 1912.

No. of Label.	Length when Liberated in cms.	Place of Recapture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Capture.
LA 502	20·5	Off Skimburness, Silloth, Cumberland	—	14.11.12	20·5	0	—

HYDROGRAPHIC INVESTIGATIONS AND THE FISHERIES OF THE IRISH SEA.

By Jas. Johnstone, B.Sc.

(With Charts.)

The variations of the salinity of the water of the Irish Sea, during the year 1912, are discussed by Dr. Bassett in another paper in this Report; and the relation of these salinity variations to the general circulation of water in this area, and to the weather of the year are also considered. The present paper deals with the temperature observations only, and an attempt is made to correlate these data with the fluctuations in the winter plaice fishery off the coast of North Wales. This attempt has not proved to be a very successful one; nevertheless, it seems to be useful to attempt to discover what results may be obtained from the data available.

I. The Temperature Observations. These are :—

(1). Semi-diurnal sea-temperatures, at the surface, at various Irish Sea Light Vessels. These observations are made for the Meteorological Office, and copies have kindly been supplied to us. The temperatures of the sea at 4 p.m. are abstracted, 10-daily and monthly means being calculated. The monthly means are given in Table I.

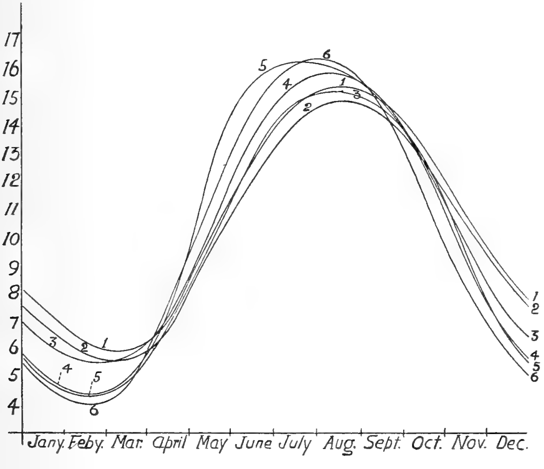
(2). Hourly temperature observations made by the officers of the S.S. *James Fletcher,* when at sea doing scientific work and police duty. These observations are carefully made, and are very numerous. Nevertheless, the cruises of the ship are necessarily restricted to certain lines and areas, and the variable nature of the police duty does not permit of all the Coastal Stations being regularly visited. Gaps in the various series of data, therefore, occur, but in spite of these the figures are of very considerable value. They have been abstracted from the vessel's temperature log-book, and monthly means have been calculated. These are given in Tables II. and III. The first column under each Station gives the number of observations made during each month; the second gives the range of dates on which the observations were made; and the third is the mean temperature. In plotting the latter data, the points graphed should, obviously, not be the middles of the monthly periods, but the median dates of the ranges shown in Col. 2. The thermometers used for these observations are "Kiel" instruments, graduated in fifths of a degree C. They are regularly compared with a Richter thermometer, which again had been compared with a standard hydrogen thermometer at the Charlottenburg Institute.

Table IV shows the mean monthly sea-temperatures at Nelson Buoy, Liverpool Bar, Great Orme's Head, Red Wharf Bay, and Point Lynus, for the whole period 1909-1912; and these data are also graphed in Text-fig. 1. Some points of interest in these data may be noticed at once. The range of variation of sea temperature is variable; it is greatest (about 12° C.) at the Lancashire Stations, Liverpool Bar, Nelson Buoy, and Piel Gas Buoy, and it is least (about 9° C. to 10° C.) at the North Wales Stations (Great Orme's Head, Red Wharf Bay, and Point Lynus). The dates of maximum and minimum temperature also vary: at the Lancashire Stations the minimum occurs about the third week in February, while it occurs about the second week in March at the North Wales Stations. The maximum also varies, occurring about the first week in August in the case of the

Lancashire Stations, and about a fortnight later at the North Wales ones.

There are two periods in the year at which the various graphs cross or approach each other closely: about the middle of April and about the beginning of October. At these times the temperature of the sea along the coast of Lancashire and North Wales is very nearly uniform.

(3). The data of the periodic hydrographic cruises. These are given in Dr. Bassett's report, but they are also plotted in Charts I to IV, where isothermal lines are drawn. On the hydrographic cruises surface temperatures are observed, as a very general rule, at points about midway between the regular stations, and also at various coastal stations. The sea-temperature at the surface



TEXT-FIG. 1. Variations of Sea-temperature at various Coastal Stations in 1912.

1, Red Wharf Bay; 2, Off Pt. Lynus; 3, Gt. Ormes Hd.; 4, Piel Gas Buoy; 5, L'pool Bar; 6, Nelson Buoy.

during the periodic cruises is determined by a Richter thermometer. The deep temperatures are observed by a Nansen deep-sea thermometer, used in the small Nansen-Pettersson insulating water-bottle. In the cruises after September of this year an Ekman water-bottle and Richter reversing thermometer were used, the other instrument being under repair.

It will be shown later that the sea-temperatures at Hydrographic Stations 5, 6, and 7, are probably of considerable importance, and it is advisable to discuss them in some detail, endeavouring to ascertain how far the individual temperatures observed on each cruise express relatively stable conditions, or are only "accidental" variations. It is necessary to consider (1) the effect of the variability in date of the periodic cruises; (2) the variation in surface temperature along the line of stations between Holyhead and Calf of Man; and (3) the variation of the sea-temperature with the depth.

(1) It is clearly impossible so to arrange matters that the periodic cruises are always made at the same dates in each year. The February cruise has been made as early as 27th January, and as late as 25th February, and the dates of the other quarterly cruises have also been inconstant (Table V.). Strictly speaking, it is impossible to compare the results of different years without making allowance for this variability, since the difference of temperature which might have taken place between (say) the 27th of January and the 25th of February, might be greater, or nearly as great as the differences between the temperatures of successive years.

It is necessary, then, to "correct" these data: to reduce them to the data which would have been obtained if the cruises had been made on the same days in each year. This might be done by interpolating from an harmonic sine and cosine formula, but the labour of this would be very great, and the results not at all reliable when only a few cruises in the year are made. It is, however, possible to deduce a "factor" by means of which the temperatures may be corrected in a simpler manner. Daily temperature readings are made at the Carnarvon Bay Light Vessel, which is not far away from Stations 5, 6, and 7, and is situated practically in the fairway of the Channel. From the known variability in sea-temperature at this point during the small periods in question, the corresponding variability at the three hydrographic stations may be deduced by supposing the changes to be parallel ones at both places. There is every reason for supposing that this is the case.

If the daily temperatures obtained from the lightship be plotted, it will be seen that those observed during a period of (say) 25 days may be regarded, without significant error from our point of view, as an "element" of the curve. That is, they may be regarded as lying about a straight line, and since the inclination of this is, of course, the same at all points, the rate of variability of the temperature function may be calculated. Let the straight line be $a + bx$, we have to determine the constant a and the coefficient b, the latter representing the rate of variation of temperature. The mean temperatures for every two or three days during each period of time covered by the quarterly cruises have, therefore, been calculated, and "moments of inertia" have then been obtained (see Elderton "Frequency Curves and Correlation, 1906) by Pearson's method. In the notation of the work cited m_0, which is simply the sum of the mean temperatures, is equal to $\int_{L_2}^{L_1} (ab + x)dx$, while m_1, which is the "first moment" is equal to $\int_{L_2}^{L_1} x(ab+x)dx$. We thus get two equations, and by solving these simultaneously a and b can be determined; a being $\frac{m_0}{2l}$ and b being $\frac{3m_1}{2\,l^3}$, l being the half range. All this is very simple and involves very little arithmetical work. What we really do is to approximate to $\frac{dt^0}{dt}$, t^0 being the temperature and t the time. Only by taking moments about the means of the periods in question can it be seen whether the temperature is decreasing, increasing, or is stationary, since the "accidental" variations from day to day obscure the trend of the curve. The daily increment of temperature thus calculated is shown in Table VI. It is of practical importance only in the months of May and November, when the sea-temperature is changing rapidly. It need hardly be applied in the months of February and November.

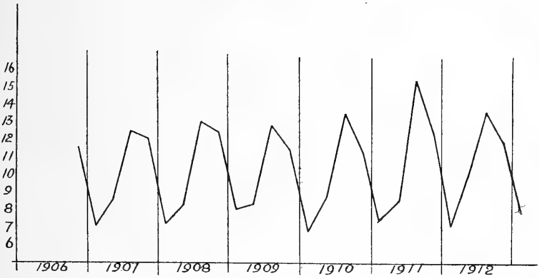
(2). The variation in temperature between various points on the Holyhead to Calf of Man line of stations, must also be considered. The stations are ten miles apart, and Station 5 is about 10 miles distant from Calf of Man, while Station 6 is about the same distance from Holyhead. The difference of temperature in a distance of thirty miles on some of the Lancashire lines of Stations may be considerable, but it is quite small on the line including Stations 5, 6, and 7. The mean temperature of each station, at each cruise during the years 1907-1912, has been calculated, and the differences are shown in Table VII. The temperature of Station 6 is regarded, in each case, as T° C., and the difference between this and the mean temperature of the adjacent stations is shown. The greatest positive difference is 0·63° in August; and the greatest negative difference 0·33° C. in February. As a rule the sea-temperatures at points midway between these stations have been observed in the cruises of the last three or four years, and it has been noticed that the variation is fairly regular, and can usually be predicted.

(3). With very few exceptions hydrographic soundings have been made on the periodic cruises at Stations 5, 6, and 7. The object of this practice has not been to investigate temperature or salinity stratification; for it was apparent, when these investigations had been in progress for a short time, that the Irish Sea, North of Holyhead, was an homothermic and homosaline water mass; and that the differences in temperature and salinity between surface and deep layers was only significant in the shallow water near the coast of Lancashire. It was seen that these differences were relatively large only in calm weather in the summer, when relatively warm and light water was carried by the tide from the heated sandbanks along the land, and overlay water which was colder and denser. Soundings are, therefore, made on the Holyhead to Calf of Man line, in order to provide a check against any " accidental " conditions, or undetected errors in the observations. The mean temperatures at the surface at each station, for each sample month throughout the period 1907-1912 have, however, been calculated (Table VIII), and also the mean differences between this temperature and that of the bottom water. The difference is, of course, negative in all cases, and is maximal at Station 5 in August, when the mean bottom temperature is 0·4° C. lower than that at the surface.

The difference between the temperature at the surface at these stations is, therefore, very small, and indicates nothing more than the small effect (on this line) due to the greater proximity to the land of the Stations 5 and 7. The differences between surface and bottom are also very small, and are almost always in the same direction. Even if there were a vertical circulation in this region (and there is no evidence whatever that this is the case), the temperature of the surface water would only be affected to a very small extent by this factor.

The water along this line extending from Calf of Man to Holyhead probably possesses a more "oceanic" character than does any other part of the Irish Sea, North of Anglesea. It will be seen from Table IX that the annual range of temperature here (5·4° C.) is less than it is at any other point investigated, and approximates closely to the yearly temperature indicated in the Atlantic Ocean to the West of Ireland. Everything indicates that the flow of water through the Irish Sea from South to North runs transverse to this line, that is, between Isle of Man and Anglesey. The drift-bottle experiments themselves provide actual evidence; which is again supported by a study of the direction of the isohalines and isotherms, since the flow of water obviously must generally take place in a direction normal to these curves at each point. It is also probable on *à priori* grounds that the flow is in this direction since the prevalent direction of strong winds is S.W. to N.W.; while Ferrel's Law shows that whatever tidal streams and currents there are in the sea here must be deflected to the East. It may be premised, therefore, that the water between Anglesey and Calf of Man represents, in its physical properties, the water further south in St. George's Channel, and even outside the mouth of the latter in the open Atlantic Ocean, and that variations of temperature and salinity at Lancashire Hydrographic Stations 5, 6 and 7 are probably parallel to those occurring outside the Channel.

For these reasons, considerable importance is attached to the physical investigation of the sea at these points, and the results of the hydrographic cruises of the years 1907-1912 are given in Table X. The figures are the means of the three stations, and only the surface temperatures are considered. The "corrected temperatures" are deduced by the method already described. The figures in brackets (May and August of 1911) do not represent the results of the hydrographic investigations since no cruises were made in 1911 except those of February and November. The mean difference between the mean temperature of the sea at Carnarvon Bay Light Vessel, during the middle ten days of May and August, in the years 1907-1912 (except 1911), and that of Hydrographic Stations 5, 6, and 7 at the same times, have been calculated; and the values in brackets represent the temperatures at the lightship, *minus* this difference. It is probable that any error so involved is insignificant: the year 1911 was obviously a year of high range of temperature, as shown by all the other results.



TEXT-FIG. 2. Mean Sea-temperatures at Hydrographic Stations 5, 6 and 7 during the months February, May, August and November of the years 1906-1913. The figures plotted are the "corrected" ones of Table X.

Fig. 2 represents these mean temperatures at

Stations 5, 6, and 7 for the years 1907-1912. The difference between the various years with respect to the annual temperature range is considerable: thus the range in 1909 is only 4·76°, while that of 1911 is 7·91°, or 8·29° if we compare August of 1911 with February of 1912. This difference is much greater than any that can be accounted for by "accidental" variations of surface temperature, or interchange of water between surface and bottom, or errors due to observation, or variation in the dates of the quarterly cruises. There seems to be no doubt that it must be traced to events occurring outside the Irish Sea, that is, to variations from year to year in the temperature of the water entering this sea area. This variability in annual temperature range is, at present, all that can safely be deduced from the data: the form of the curve does indeed suggest a periodicity in these variations, a periodicity which is exhibited best perhaps in the amplitude of the annual temperature wave, and in the value of the figures for the "mean" months—May and November. But, obviously, the period of years throughout which the observations have been carried on is too small to allow of the deduction of conclusions of this kind.

II.—Temperature Differences in the Eastern Side of the Irish Sea.

Even in this very limited sea-area these differences are fairly considerable, and this is because there are two main series of conditions: (1) The effect of the very extensive sand-banks fringing the coasts of Lancashire and Cheshire, and tending to produce great temperature differences; and (2) the effect of the relatively strong inflow of water round Anglesey from the open Channel: this tends to reduce temperature differences, in the regions influenced, to a minimum. Table IX shows the mean temperatures for the four sample months, February, May, August, and November, at a number of stations, coastal and off-shore ones. The means have been calculated for the four years 1909-1912 only, since these are the only years for which temperature records for the coastal stations are available. It will be seen that there is an area of sea extending from about Morecambe Bay to the Mersey Estuary—bounded roughly by the parallels of latitude 54° 00′ N. and 53° 30′ N., and by the meridians 3° 00′ W. and 3° 30′ W.—where the annual temperature range is relatively great; and where the minima are low and the maxima high. Thus at the Stations, Morecambe Bay and Liverpool North-West Light Vessels, at Nelson Buoy, and at Liverpool Bar the range varies from about 10° C. to 12·5° C., the minima from about 4° to 6°, and the maxima from about 15·5° to about 16·5°. This part of the sea is influenced by the strong tidal streams which oscillate between the sandbanks in the bays and estuaries, and the open sea off-shore. The great extent of sand laid bare by the ebb-tide cools the water flowing over it in the winter months, and warms it to a corresponding extent in the summer. This area includes most of the summer fishing grounds for soles and plaice.

The mean temperatures for the two principal series of hydrographic stations are also given in the Table. Stations 1 to 4 lie along the 54th parallel of latitude, Station 1 being about 10 miles from the land, and it and the others are 10 miles apart. The temperatures at these stations do not differ very much in the months May and November, but in February, the month of the minimum, the temperature falls as we pass out from the land, while in August, the month of the maximum, the reverse condition holds good: the annual range of temperature therefore decreases with the distance of the station from the land. The second line of Stations 5 to 7 lie on a line between Calf of Man and Holyhead, and are nearly equidistant on either side from the land and from each other. There is much more uniformity at these points. Station 7 is about ten miles distant from Holyhead, and is probably affected slightly by the tidal stream which enters Carnarvon Bay as an indraught, and sweeps out again; but Stations 5 and 6 are probably not at all affected in this way, and their annual range of temperature is only about 5·5°, a value which is not much greater than of the water in the Atlantic Ocean west from Ireland. Midway between Isle of Man and Ireland, and in an area including these three stations the physical condition of the sea is probably more uniform than in any other place north of Anglesey: it is here that critical and really quantitative experiments would probably indicate a high degree of uniformity in the distribution of pelagic life. Nearer the land, on either side, the physical conditions become much more complex, as the sea becomes more shallow, and the influence of the tidal streams becomes apparent. The annual range of temperature at Port Erin is very much the same as that off the coast of Anglesey between Carmel Head and Point Lynus. There is hardly any trawling in this part of the Irish Sea, nor round the south end of the Isle of Man on the one hand, nor off the coast of Anglesey between Point Lynus and South Stack on the other.

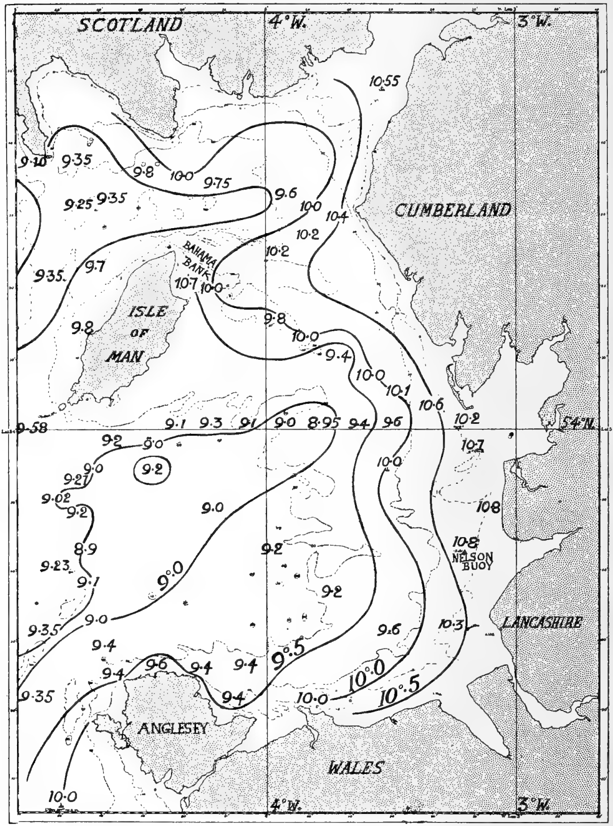
The sea between Point Lynus and the Liverpool North-West Light Vessel, south from about parallel 53° 30′ N. is intermediate in physical conditions between the two areas mentioned. There are few large sandbanks along the coast of North Wales, and those of

Liverpool Bay are too far away to exert any appreciable influence; hence the temperature of the water here is not influenced by the land to the same extent as it is off the coasts of Lancashire and Cheshire. The main drift of water is from St. George's Channel round the coast of Anglesey into Red Wharf and Beaumaris Bays; and since this water is colder in the summer, and warmer in the winter than that normally present in the sea off Liverpool Bay and the coasts of North Wales, so the temperature in this area is more uniform than it would be in the absence of this inflow. Still the land does exert an influence, and so the temperature range in these areas is greater than it is in the fairway of the Channel. The very important winter plaice fishing grounds in Red Wharf Bay, off Point Lynus, in Beaumaris Bay and off Great Orme's Head, and in Channel Course (that is, in the track of vessels approaching Liverpool Bar from Point Lynus) are situated in this area.

These temperature differences are best shown by the isothermal lines plotted on Charts I to IV. The chart drawn for February is for 1913, since the only hydrographic stations visited during February, 1912, were those on lines 1 and 2, and these points are insufficient to define the isotherms exactly. It should be noted that these charts represent the differences of temperature in a broad manner only, and that much more numerous observations would certainly show that the isothermal lines run more irregularly than represented, although their general direction might still be the same. It is very probable that they are quite sufficient for the investigation of any relationship between temperature and fishery periods or productivity that may possibly exist.

Chart I represents the distribution of temperature during May—one of the "mean" months. The prin-

CHART I.

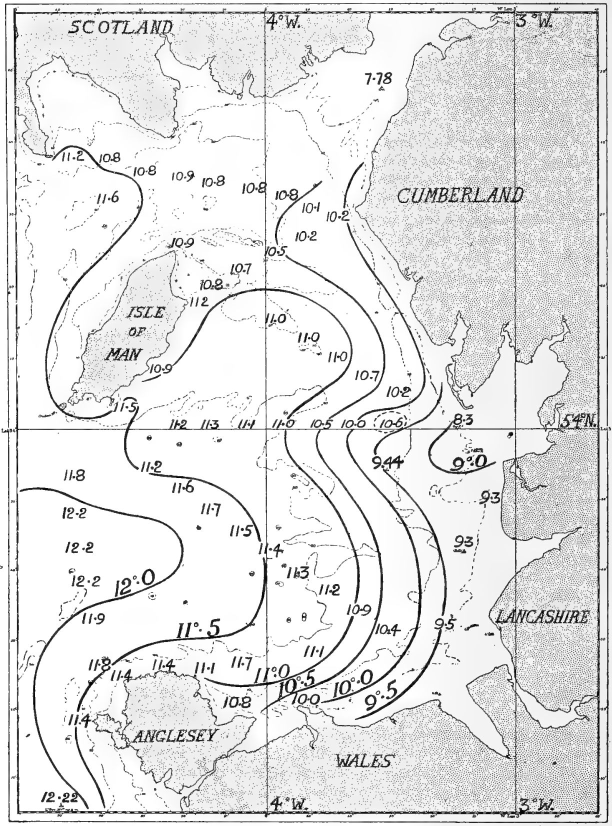


Isotherms in the Eastern part of the Irish Sea during May, 1912.

cipal feature is the approximate uniformity of temperature over the entire area. There is a large, irregular patch of water in the middle of the Irish Sea, where the temperature is about 9° : the narrow tongue which is seen to pass to the west of Anglesey terminates a little way to the south, as the observations made by the Irish Fishery vessel "Helga" during this month show. Near the coast of Lancashire are the highest temperatures observed, 10° to about 11°. Everywhere in the area covered by the isotherms the gradients are slight, that between Nelson Buoy and Red Wharf Bay being about 1·5°, while between the former point and the Bahama Bank, the gradient is less still. Along the line of Stations between Piel Gas Buoy and Bahama Bank the isotherms run rather irregularly, a condition which is to be traced to the rapid tidal streams which oscillate in this direction between Morecambe Bay and the sea off-shore, and also to the fact that the sea-temperature is rising rapidly at this time of year: the daily increment at Carnarvon Bay Light Vessel is about + 0·08. At this time of year the highest temperature gradients are those at right angles to the coast line of Lancashire, the isotherms running nearly parallel to this, and being closest to one another here.

Chart II represents the distribution of temperature during November, the other "mean" month. There are notable differences, however, in the course of the isotherms at this time of year. The sea-temperature is rising rapidly in May, but falling less rapidly in November, the daily increment during this month at Carnarvon Light Vessel being − 0·038 in degrees Centigrade. The water off-shore is warmer than that in-shore in November, but colder in May. There is a tendency for the isothermal lines to bend in towards the coast of

CHART II.



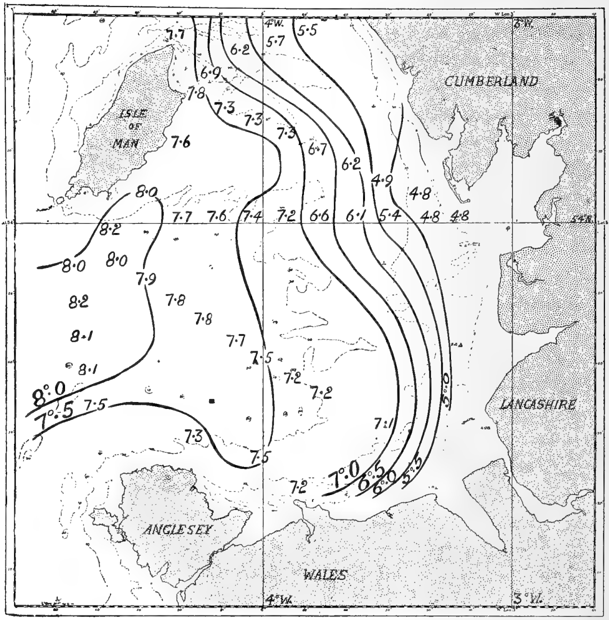
Isotherms in the Eastern part of the Irish Sea during November, 1912.

North Wales in November, but to bend upwards towards the east side of the Isle of Man in May. The direction of the general drift of water is indicated by straight lines drawn normal to the isothermal curves; hence the main drift of water in November (and in February) appears to be round the coast of Anglesey into the sea off the coasts of North Wales and Liverpool Bay; while in May (and in August) it rather appears to be towards the sea between Isle of Man and Cumberland. At any rate, these appear to be the general directions along which temperature changes are occurring.

The temperature gradients during this month are steeper than they are in May. That along the line of Hydrographic Stations 1 to 4 is nearly 3°; between Nelson Buoy and Bahama Bank it is about 1·5°; and between Nelson Buoy and the Red Wharf Bay fishing area it is very much the same. A further important condition may be noted: there are two areas of relatively warm water, (1) just South of Bahama and King William Banks, and (2) just North from Red Wharf Bay and Great Orme's Head.

Chart III represents the conditions in February, 1913 (the other Charts relate to 1912). The course of the isotherms cannot be very precisely indicated for this month since the data for the light vessels and the various coastal stations have not been obtained at the time of writing. It is, however, added here in order to amplify the general argument of the paper. It shows that the conditions represented by the temperature distribution of November still exist, and that the differences and gradients shown in the chart for that month are accentuated in February, when the process of cooling on the one hand, and the progress of the drift from the Channel round into Liverpool Bay are attaining a maximum. There are still two areas of relatively warm water situated in relatively shallow sea areas, (1) the Bahama, King-William Bank areas, where the temperature is about 7°, and (2) the Red Wharf area, where the

Chart III.



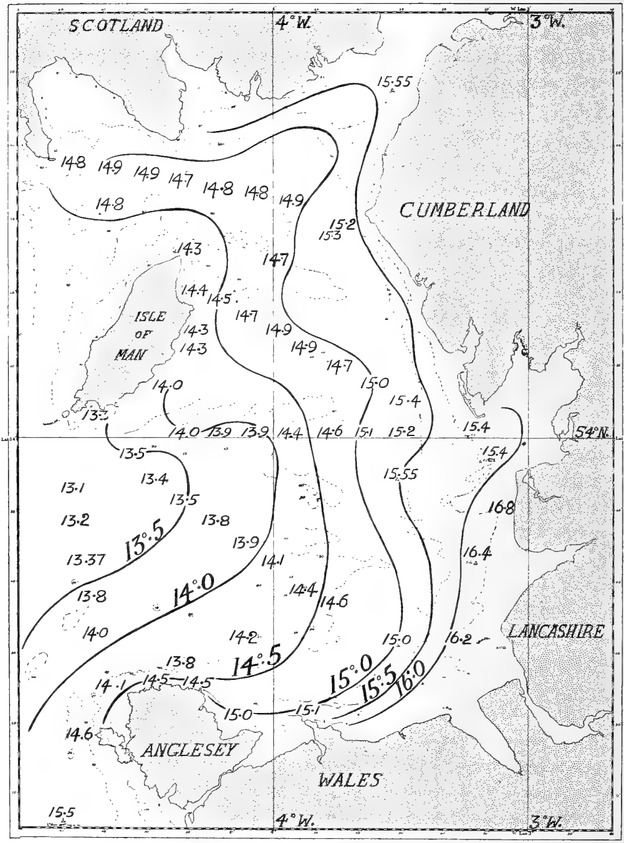
temperature is about the same. The shape of the isotherms show that at this time both areas are about equally affected by the inflowing warm water from the South-West. The gradients are now much steeper: that along the line of Stations 1 to 4 is about 5° to 8°; that from Nelson Buoy to BahamaBank is about 4° to 7°; while that from Nelson Buoy to Red Wharf Bay is about the same. Off the Estuaries of the Ribble, Dee, and Mersey, the gradient is steeper still: this is the coldest part of the whole Irish Sea in winter, with the exception of the upper reaches of the Solway Firth. Centrally the gradients are small, and the temperature is very uniform over a wide area. So much can be deduced from the incomplete observations of February, and the general trend of the isotherms, while subject, no doubt, to slight alterations, will probably remain the same when all the observations are obtained.

The period of maximum temperature is represented by Chart IV, which represents the conditions on 15th August, 1912. The highest temperatures, about 16° to 17°, are now found close in-shore, and the lowest in the central sea-area south from Isle of Man. The gradients are fairly steep, and lines drawn normal to the isotherms would run approximately at right angles to the general trend of the coast line, since the isotherms run roughly parallel to the latter. So far as the latter indicate the direction of inflowing water, this appears to be more towards the sea between Isle of Man and North Lancashire, than round Anglesey into Liverpool Bay.

III.—Temperature Conditions and Fish Migrations.

The general conditions existing in the Irish Sea during the summer of 1912, and the winter of 1912-13 are represented in the Tables and Charts which have been discussed. Summarising them, it may be stated that the differences in temperature in different parts of this area are relatively considerable at two periods of the year, (1) the months December to February, when the sea is

Chart IV.


SCOTLAND
4°W.
3°W.
15·55
14·8
14·9
14·9
14·7
14·8
14·8
14·9
14·8
CUMBERLAND
15·2
15·3
14·3
14·7
14·4
14·5
ISLE OF MAN
14·7
14·3
14·3
14·9
14·9
14·7
15·0
14·0
15·4
13·3
14·0
13·9
13·9
14·4
14·6
15·1
15·2
15·4
54°N.
13·5
15·4
15·55
13·1
13·4
13·5
16·8
13·2
13·8
13°·5
13·9
16·4
13·37
14·1
14°·0
13·8
14·4
14·6
14·0
14·2
15·0
16·2
LANCASHIRE
13·8
14°·5
15°·0
14·1
14·5
14·5
15°·5
16°·0
15·0
15·1
14.6
ANGLESEY
WALES
15·5
4°W.
3°W.

cooling down towards the minimum; and (2) in the months June to August, when the sea is warming up towards the maximum. Although the whole area under consideration is quite small, yet the different parts present differences which seem to be of significance, if it is assumed that physical changes may be factors which influence the migrations of fishes. The whole sea does not, in fact, heat up and cool down at the same rate in its different parts, and it is probable that these differences, with the temperature gradients which they set up, may be the factors of fish migration to be investigated.

The assumption that temperature changes are factors of this kind is probably justified by all that is known of the life history of fishes. The rate of development of the egg, and the length of the periods between fertilisation and hatching and metamorphosis are certainly affected by the temperature, and it is very probable that an empirical formula might be obtained from sufficient data, that would enable these periods to be calculated, the temperature being known. The rate of growth of adult fishes is also probably affected by temperature, and so also with the relation of length to weight: fishes of the same length are heavier in summer than they are in winter. During the colder winter months plaice either do not feed at all, or, as a rule, contain little in their alimentary canals. The rate of metabolism of fishes is certainly affected by changes of temperature: the frequency of the respiratory movements of the mouth and gills, for instance, which varies with the temperature. Generally speaking, all these things are particular cases of van't Hoff's law, that is, the rate of a chemical reaction is a function of the temperature at which it is carried on: the vital processes which have been mentioned above are all cases of directed chemical reactions.

There can be little doubt that there are optimal conditions of temperature for plaice of different ages; that is, growth occurs most rapidly when the temperature is at a certain value, and this must be the case even when food is abundant, for digestion and assimilation must proceed most rapidly at such an optimal temperature. The scarcity and abundance of food is, perhaps, a factor of less importance than might at first be supposed: on such a coast as that of Lancashire, Cheshire, and North Wales the crustacea and shell-fish on which plaice of different ages feed are generally very abundant somewhere or other on the fishing grounds. Local scarcity of food may, indeed, lead to migrations, but these are merely the local ones, occurring indiscriminately in many directions, which are indicated by the marked fish experiments. There are instances of great abundance of plaice on various restricted parts of the sea bottom where food is abundant: such, for instance, was the case near West Hoyle Bank, at the entrance to the Estuary of the Dee in the year 1910; or the local abundance of plaice in Rock Channel, off the Estuary of the Mersey, a phenomenon observed many times; or the local abundance of small plaice at the entrance to Walney Channel in Morecambe Bay. In all these cases food of some kind was particularly abundant on the areas mentioned: *Mactra* and *Scrobicularia*, in the case of the West Hoyle Bank shoals; *Cardium* and *Pectinaria* in Rock Channel; and small *Mytilus* in Walney Channel. So also with many more similar instances which might be observed, if particular attention were paid to the question of the association of fish shoaling with changes in the bottom fauna. But all such migrations and segregations are apparently aperiodic; they do not recur, or if they do, the recurrence cannot be predicted. In a certain sense they are "accidental"; that is, they are due to the operation of a multitude of small causes.

It is hardly possible to attempt to correlate changes in the nature and abundance of the plankton with the aperiodic migrations or segregations of plaice, or still less with the larger migrations which experience shows are repeated with a certain regularity from year to year. It would, indeed, be possible to trace a possible connection between the abundance of vegetable plankton and the local abundance of small shell-fish on particular parts of the sea bottom, but it seems clear that the demonstration of this relationship is impossible by existing methods of investigation. It is not yet certain what is the kind of food on which these small shell-fish subsist, whether it is organised food in the shape of phyto-plankton, whether it is dissolved organic matter in the sea water, or organic detritus in the sea-bottom deposits. Until this question has been fully investigated, it seems impossible to expect that the food of the plaice and other bottom-living fishes feeding on benthic animals can be traced back to the phyto-plankton; and changes in the habitat of food, and fishes eating it, related to changes in the plankton contents of the sea.

It is probable that salinity changes may be factors of significance in determining the nature and times of the migrations made by such fishes as plaice. But this question is not discussed in the present paper. The salinity changes that occur from time to time, and from place to place are, indeed, fairly large in the Irish Sea, though they are less in value, and far less easily observed than the corresponding temperature changes. It is, nevertheless, far more difficult to suggest a hypothetical relationship between salinity changes and changes in the metabolism of fishes, than it is in the case of the temperature. It is, of course, possible that some internal change is produced when a fish moves from water of relatively low to relatively high salinity, or *vice versa*: the nature of the processes controlling diffusion through the epithelia of the gills, or other surfaces, must undergo change in such an occurrence. It is also possible that there is an optimal salinity for the fish as well as an optimal temperature and an optimal pressure of water, but the investigations so far made do not suggest what these optimal salinities are. The question of the salinity is one of very great difficulty, and its investigation would involve salinity determinations of the water at very numerous stations, and very often throughout the year, since the changes in-shore are probably relatively complex. No attempt is, therefore, made to investigate this possible relationship.

It is almost certain that there are optimal temperature conditions for plaice of different ages, but it is impossible, in the meantime, to say what these are. They are susceptible of investigation, and might be determined with a fair degree of accuracy. It was with this object that samples of plaice were obtained, and the length-weight coefficient k evaluated for different fishing grounds and seasons. The method is certainly quite a sound one, for the value of k, that is the "condition" of the fish as regards nutrition, must be an index of its rate of metabolism. No data of this kind are, however, yet available, since it has been found impossible, after four years of investigation, to obtain the complete series of plaice samples, with the temperature records of the fishing grounds when they were caught, which would allow the estimates to be made.

The hypothesis may, however, be made that there are such optimal conditions of temperature, and that changes in these conditions, that is, rise or fall of temperature, as the case may be, are the proximate causes of the migrations of plaice which are to be mentioned. It may safely be assumed that these periodic migrations are really *adaptations.* The fish is living under conditions of a certain kind, and its functioning is of a certain nature. When the conditions change the fish responds, not by a change of structure, or functioning, in the special sense, but by a migration into another area where the conditions are similar to those of the area in which it was previously living. In general, it will be the case that the adaptation brought about by such a migration will be incomplete, that is, the fish will not be able to remain within optimal conditions by making a migration, but the object of the latter movement is, no doubt, one of this kind.

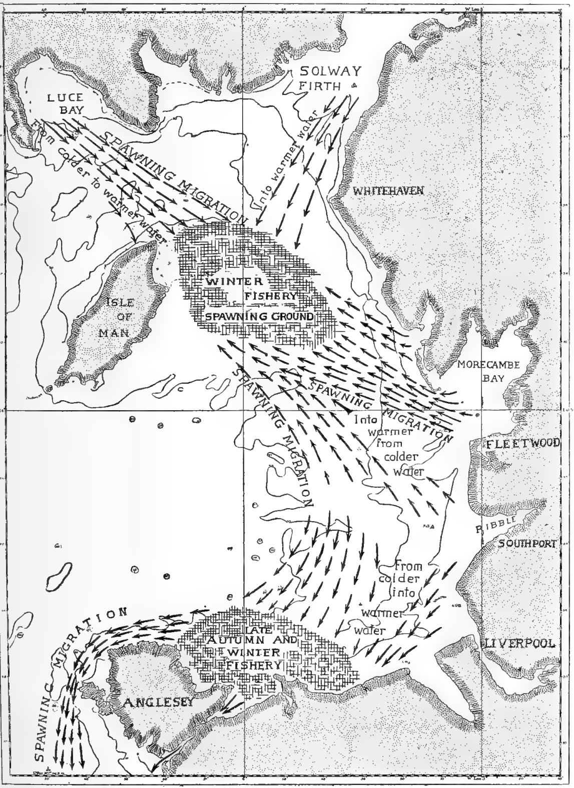
This is probably, to some extent at least, the meaning of many kinds of fish migration; that of the Mackerel, Bass, Garfish, and some other species into the Irish Sea. In these cases the fish, experiencing a rise of temperature in the seas to the South and West, in the mouth of the Channel, endeavours to correct this by migrating to the North. But it may also be the case that the meaning of such migrations is also the effort of the fish to enlarge its area of distribution: as the temperature rises in adjacent areas it moves into those regions. This may be the nature of the migrations of the Cod and Whiting into the Irish Sea during the early months of the year. These fishes, living in colder waters to the North, migrate to the South as the temperature there falls and approximates to that of the sea-area in which they find their optimal conditions. If this hypothesis is sound, it ought to be possible to predict the time of maximum appearance of Cod in the northern part of the Irish

Sea by studying the temperature gradient during the last months of the year in the sea further to the North.

This explanation of the migrations of plaice in the Irish Sea was suggested by me in 1911, and I reproduce here a chart which was then made for another purpose. Chart V was based on the plaice-marking experiments carried out in 1906-10, and shows the main results of the latter; distinguishing between such adaptive migrations as have been considered above, and real spawning migrations—movements which, however, might be regarded as having very much the same meaning.

It is impossible to present here the detailed evidence on which the above chart was constructed, since the hydrographic investigations of the years in question were not complete enough to allow of the construction of charts showing the isothermal lines. In 1912, however, the marked-plaice experiments were begun again, on, it was hoped, a larger scale, and according to methods utilising the experience attained in the earlier investigations. These extended experiments have, unfortunately, not been made, but two fairly large lots of plaice were marked by me (1) in June, 1912, on the summer plaice fishing grounds near Nelson Buoy, and (2) in October on the same grounds. The summer experiment was made in order to investigate the movements of the fish about the time when the marked segregation on this ground, which is always observed from year to year, had fairly been established. In October, or thereabout, the plaice begin to desert this ground. "Practical" men say that they have been fished out, but this is certainly not the case, and the disappearance of the fish is due to their migration into other fishing grounds. The experiment in October was made in order to show the nature of these migrations. In each case about 200 plaice of lengths

CHART V.



General scheme of plaice-migrations in the winter months based on the results of the marking experiments.

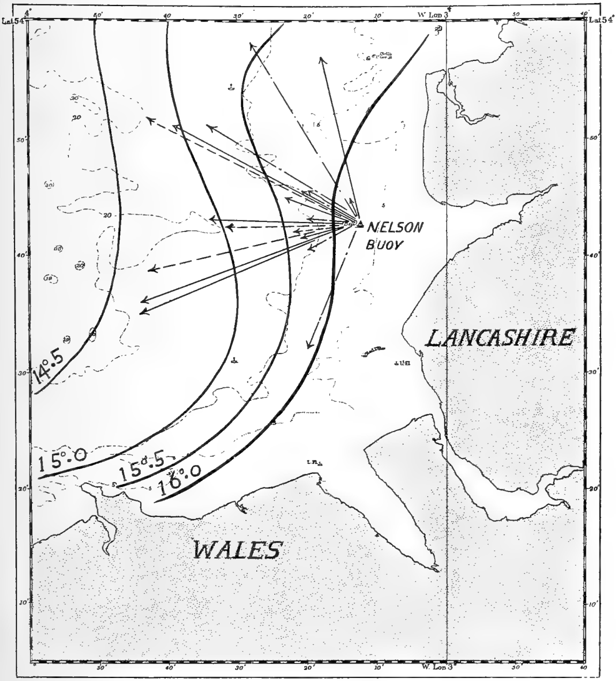
varying from about 19 to 35 centimetres were marked and liberated. In neither case was the condition of the fish very satisfactory since they had been rather roughly handled in the course of the trawling by which they had been caught, but quite enough were liberated in a condition sound enough for the purpose designed.

The summer migration may be considered first since this is not shown in the chart on p. 301. Eighteen fish are recorded: these were they returned during the months of June, July, and August. The months of recapture are indicated by the lines representing the hypothetical paths pursued by the fishes caught. Continuous lines represent the June-caught fish, broken lines those caught in July, and lines and dots those re-captured in August. The heavy lines are isotherms for the middle of the whole period—August 15th. Chart VI shows these migrations.

The number of fishes recaptured is, it is true, few, but the nature of the migrations made are almost precisely similar to those observed in the recaptures of previous years in two experiments made on this ground at about the same time. It is, therefore, quite justifiable to conclude that these migration paths are not "accidental" nor unusual ones, but really represent those followed by plaice living on this fishing ground at this time of year. There were a few other fishes returned during the same months, but the place of recapture of these was uncertain, and they are not included in the chart.

The latter shows clearly that the migration paths are, in the main, perpendicular to the direction of the isothermal lines; they *cross* the latter, very generally by the shortest routes. It is true that the paths are not exactly transverse to the isotherms, but the latter have been drawn for the middle of August. It is quite likely that had a great number of fish recaught in June, after liberation during the same month, been available, and had there been isotherms available for that month, the

CHART VI.



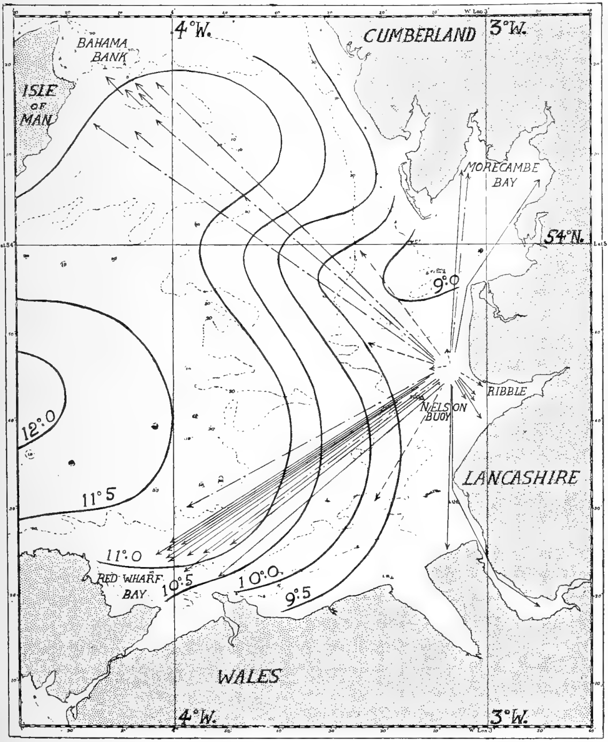
Ordnance Survey Southampton 1914

correspondence with the hypothesis would have been more exact. So also with the other two months: there is no doubt that there will be a significant variation in the shape of the isothermal lines during these three months. It is also to be noted that the straight lines on the chart do not necessarily represent the general direction of the tracks followed by the migrants. They are the only lines that may be drawn for this purpose, and it is quite possible that the fish in many cases may have travelled along a curved track, thus crossing the isotherms more transversely than is indicated in the chart. The absence of any recaptures in the in-shore waters of the bays and estuaries during these months is very striking, also the absence in the fishing grounds off the coasts of North Wales and the Isle of Man. There can be no doubt that plaice of the range of lengths represented by the experiment are moving out from the shallow water in-shore towards the deeper water off-shore during the time of increasing and maximal sea-temperature. But it is also clear that the migration is not necessarily from shallow to deep water, that is, it is not increasing pressure that the fish is attempting to attain, but rather a lower temperature. It is moving from warm water into cold water, *at the time when temperature of the latter at its point of departure is rising.*

Chart VII represents the results of the experiment made in October; and also those recaptures of fish, liberated in the June experiments, which were made in the months of October, November, and December. The thick lines are again the isotherms for November 15th, 1912. The months of recapture are indicated by the nature of the lines representing the tracks of the fishes: the broken lines represent recaptures in October; continuous lines those in November, and lines with dots those of December. It will be seen that a number of plaice (10) have migrated into Morecambe

Bay, the Estuary of the Ribble, and that of the Mersey. Such along-shore migrations have always been observed in previous experiments. They represent the capricious, or aperiodic migratory movements already referred to.

CHART VII.



But it will also be noted, not only from this, but also from previous experiments that they occur mainly during the winter months.

The conspicuous off-shore Westerly migrations of the summer experiments are almost quite absent. Instead of these the migration paths fall into two groups, (1) towards the fishing grounds off the coast of North Wales into the Red Wharf winter plaice grounds; and (2) towards the winter plaice grounds to the South and East from Bahama Bank. Twelve fishes have taken the former course, and three fishes the latter: not a very great number, but since these results, again, are entirely confirmatory of those of the similar experiments of former years, we are thoroughly justified in regarding them as typical and truly representative of a much larger number of migrations. Five other recaptures are represented on the chart as having been made on the Bahama area: these are shown by the arrow-heads without lines connecting them with the place of liberation. They were plaice recaptured in January and February of 1913, and they are not treated like the rest since it is uncertain how they have migrated: they may, for instance, have travelled North from the Red Wharf Bay area. It is, however, fairly probable that they are fish which took part in the migration that is indicated by the lines and dots, and that they have remained on the Bahama Bank area for a month or so longer without being recaught.

With the exception of the ten fishes which have made the along-shore migrations, all the others move in such a manner as to support the hypothesis indicated above. Those plaice which have migrated into Red Wharf Bay have moved out of water at a temperature of about 9° into water at a temperature of about 11°. So also in the case of the plaice migrating into the Bahama, King-William Banks area; the rise of temperature accompanying this migration is also about 2° C. The adaptation brought about in these winter movements is the same as that achieved in the summer ones: the fish, experiencing a change of temperature moves in such a manner as to make this change minimal. In the summer it moves out of water rising in temperature into colder water; and in the winter it moves out of water falling in temperature into warmer water.

The majority of the migrations studied by the marking experiments are not spawning ones. The greater number of the plaice liberated are quite immature: practically all the females are, and only a small proportion of the males are sexually mature. The plaice fisheries in Lancashire waters are essentially fisheries for immature fish, and it is only in the late summer and autumn months that a few larger mature plaice appear in the shallow waters. The question of migration as an adaptation to temperature change is not therefore complicated by the simultaneous occurrence of spawning migrations, at least not to such an extent as seriously to affect the conclusions made here. Migrations of sexually mature plaice, or plaice about to become sexually mature, do indeed occur: thus, relatively large plaice move from Luce Bay (on the South coast of Scotland) to the shallow water banks off Ramsey, in the Isle of Man. Some, also, of the plaice inhabiting the in-shore waters off the Lancashire and Cumberland coasts may migrate towards this area. There is no doubt that the most important (perhaps the only) spawning area in the northern part of the Irish Sea is this area off the North-East coast of the Isle of Man. It is a fishing-ground which would well repay investigation, in view of the results of the marked-fish experiments of this and former years; but, unfortunately, the few observations made on it are of no value at all for the purposes of this discussion.

There is more information with regard to the winter plaice fishery in the Red Wharf Bay area, but this has been derived almost entirely from the measurements of plaice made there by the S.S. "James Fletcher," and from the samples of fish sent by the officers of that vessel to the Laboratory. Unfortunately little or nothing is known as to what proportion of the larger fish caught in this area during the latter part of the year are sexually mature, or whether or not they actually spawn there. It is, however, unlikely that they do, so that in this case the migrations appear to be governed by the temperature-adaptation factor.

It is assumed here, as a working hypothesis, that changes in the productivity of the fisheries from year to year are due entirely to differences in the periodic migratory movements made by the fishes themselves. It can hardly be believed that the cause of a bad plaice fishery in the Irish Sea (say) during a certain winter is that the fish are actually less abundant over the entire area than they were during the previous winter, when the fishery was a good one. It may be the case that the actual quantity of fish inhabiting the whole area is decreasing slowly from year to year, although there is no indubitable statistical evidence in favour of this statement. But the actual difference between the total catch of plaice, in a certain fishing area, in two successive years, may be far too great to admit of the conclusion that the whole area had become depleted to such an extent. What does actually occur is that there are differences from year to year in the degree of segregation of the fish on definite fishing grounds. These differences of segregation are, in turn, due to differences in the migration paths taken by the fish as the result of adaptation to change of temperature, or of salinity, or of both. The total quantity of plaice in such an area as the Irish Sea, with St. George's Channel, probably remains much the same from year to year: if fish are scarce on one particular fishing ground they are more than usually abundant on others; admitting, of course, that a progressive slow change may occur, a change which is nevertheless too gradual to produce a very notable effect in the productivity of two successive seasons.

If this is the case, the relation between changes of physical conditions and changes in the productivity of the fisheries ought to become apparent by following up the line of investigation suggested in the previous pages. In order that it may be successful this method requires a knowledge of accurately collected fishery statistics. Fortunately, the system of collection adopted by the Board of Agriculture and Fisheries some years ago provides at least the machinery for the collection of these data. The "D 2" forms now in use by the Board's Collectors of Statistics contain information with regard to the quantity of each kind of fish landed by all first-class fishing vessels (steamers and smacks); the duration of the "voyage"; and the locality of the ground fished over.

These "D 2" forms for the years 1906-1912, and for all landings of fish at the Port of Bangor, in North Wales, have been sent to me by Dr. J. T. Jenkins, and they have been examined and abstracts of the quantities of plaice landed day by day, during this period, from the fishing grounds off the coast of North Wales, have been made. The grounds in question include Red Wharf Bay itself, and the deeper water off-shore from it and Point Lynus down to about 20 fathoms; the fishing grounds in

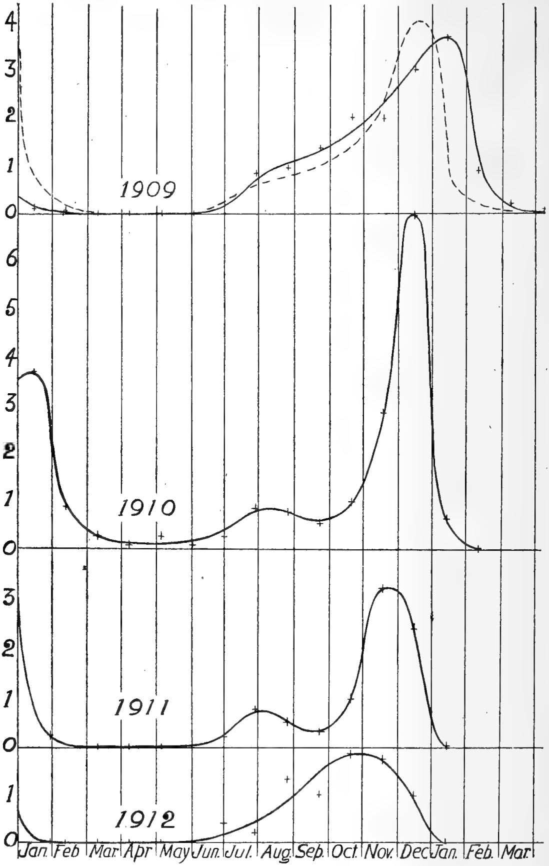
Beaumaris and Conway Bays, and off Great Orme's Head, in Carnarvonshire; and the grounds in "Channel Course," that is, the tract of sea between Point Lynus and the Liverpool North-West Light Vessel. The area is rather large, and perhaps better results might have been obtained by considering only the fishery in Red Wharf Bay, but it is often the case that a vessel is returned as having fished both in Red Wharf Bay and in Channel Course, or in Red Wharf Bay and off Great Orme's Head, or in Red Wharf Bay and in Conway Bay. There seems to be no alternative to combining these various grounds in one, rather heterogeneous, area.

The immediate results of this study of the statistics are given in Table XIII. The entries are means for each week of the period, a week meaning the days from Sunday to Saturday (both included). The first column under each year gives the total number of days' fishing recorded in the forms filled up for the week; the second column the total quantity of plaice, in cwts., caught during the week; and the third the mean catch, in cwts., per day's trawling.

Only first-class sailing vessels (smacks) furnish these returns, and the results represent the effect of the fishery of a fleet of vessels varying in number from about a dozen to thirty. Steam trawlers also fish on this ground, outside the territorial limits, and a certain (small) number of third-class fishing boats may also trawl at times. Neither the steam trawlers nor the third-class vessels furnish returns to the Collector of Statistics at Bangor, and the conclusions which may be drawn from the summary are valid only if it is assumed that the results of the fishing operations of the small fleet of smacks represent the relative abundance of plaice on the grounds. It is probable that this conclusion is a correct one.

In the original statistics themselves the plaice caught are recorded as "large," "medium," "small," or "size not distinguished." No attention has, however, been paid to this classification, and the plaice are indeed almost all returned as "large"; only very occasionally are they said to be "medium." It is certain that an ordinary catch of plaice from these grounds cannot properly be described as consisting of "large" fish. The lengths of the fish caught will be seen by referring to the tables of plaice measurements made in this area during the years 1909-1912 by Captain Wignall, of the Lancashire fishery steamer "James Fletcher." These tables are published in previous reports. What is found in this area is a plaice population of a high range of lengths, 10 to 50 centimetres, a range which is only exceeded in the Irish Sea area by that of the plaice caught in Luce Bay, where fish of 62 cms. in length have been taken. The distribution of age and sex is also tabulated in the Reports, but these figures have been obtained only by the examination of monthly samples of about 100 fish each during the various seasons. Unfortunately very few observations at sea have been made, and the figures of the sample catches do not give a reliable estimate of the proportions of sexually mature plaice on the grounds.

The progress of the fishery is well shown in the tables given in this paper. Table XIII shows the mean daily catch for each week for the period 1907-1912, and Table XII the mean daily catches for each month for each of the years, and the mean daily catch for each month for the whole period. Fig. 3 represents the mean monthly catches for each of the years 1909-1912, and the mean monthly catch for the whole period 1907-1912 as the dotted line superposed upon the curve for the year 1909. The latter curve gives a general picture



TEXT-FIG. 3. Mean quantities of Plaice (in cwts.) caught per day's fishing in the North Welsh Winter Plaice fishing area during the years 1909-1912. Figures on the vertical axis represent cwts. The dotted line superposed on the curve for 1909 represents the mean catch for the whole period.

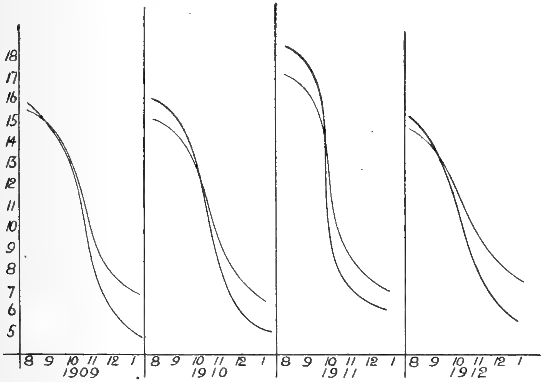
of the yearly progress of the fishery which is probably not far from the truth. Practically no fish are caught during the months of April and May; the catch then rises at first rapidly and then more slowly till November, when it rises rapidly to its maximum about the end of December. The mean catch then falls very rapidly towards the minimum, in March. The drop at the end of December is generally very striking, but this is due, to some extent at least, to the fact that most of the boats cease fishing during the Christmas week.

The different years show fluctuations which appear to have a real existence. The year 1909 was exceptional in that the fishery did not rather suddenly cease about the end of December, but continued on into the January and February of the following year, attaining its maximum in January. The fishery was again exceptional in 1910, not only in that a certain noticeable quantity of fish was caught throughout the entire year, but in that the quantity caught during December was greatly above the mean. In 1911, the fishery during November and December was below the mean, and in 1912 the lowest catches during the four years were made.

In all the years the fishery appears to begin during June. But the time of the maximum varies from year to year: it was in January in the winter of 1909-10, in December in 1910, about the end of November in 1911, and about the end of October in 1912.

Assuming that these statistics really represent the progress and productivity of the fishery—there are no means apparent of checking their accuracy, and we must make this assumption—some relation between the fluctuations in productivity and the date of the maximum may be sought. The only hypothesis which seems to be suggested by the study of the experimental and hydrographic investigations carried out in the Irish Sea is that the plaice fishery in Red Wharf Bay and the adjacent grounds is the result of an extensive immigration of fish into this area from somewhere else. The rapid falling-off in the productivity of the fishery during the latter weeks of the year must also be due to the emigration of plaice from out of the North Welsh fishing grounds into some other area—that is, unless it is the case that the vessels simply cease to fish for some other reason than the scarcity of plaice. If the fishery ceased because the grounds were becoming depleted by the intense fishing of the few last weeks of the year, the curve of catches would fall more slowly than it does. It also appears to be really the case that the plaice have actually disappeared from out of Red Wharf Bay by the beginning of the year, for the trawling experiments made by the "James Fletcher"—such as they are: there is a regrettable lack of these during January and February—show that fish are then very scarce. It must therefore be concluded that the fish do actually migrate out from the Bay. The marking experiments support both of these assumptions: it is the case that relatively large numbers of marked plaice migrate into this area from the fishing grounds further north and east, it is also the case that a fair proportion of plaice marked in Red Wharf Bay during the progress of the winter fishery have been recaptured in other fishing grounds, principally in Cardigan Bay and off the South-West coast of Ireland, though some have also been taken on the Bahama Bank grounds.

If the aperiodic fluctuations in the values of the mean catches made are due to differences in the quantities of plaice migrating into or emigrating out from this area, or if these migrations are adaptations on the part of the fish to temperature changes, then it ought to be possible to correlate the differential temperature changes with the fishery statistics. The greater the drop of temperature in the Nelson Buoy area, for instance, in comparison with the fall of temperature in Red Wharf Bay, the greater should be the migration from the former area to the latter. It was with the object of testing this supposition that the temperature tables in this paper were calculated. Fig. 4, for instance, is an attempt to represent the temperature differences at the two fishing grounds. The low-range curve is that for the mean of the two stations Nelson Buoy and Liverpool Bar; and the high-range curve is that for the mean of the three stations Great Orme's Head, Red Wharf Bay, and Point Lynus. There are certainly differences between the various years, for the



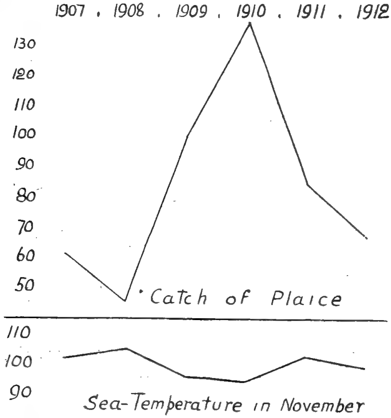
TEXT-FIG. 4. The mean fall of temperatures at the stations Liverpool Bay and Nelson Buoy (high range curve), compared with the fall at the stations Red Wharf Bay and Great Orme's Head (low range curve). Figures on the vertical axis are degrees centigrade, on the horizontal axis months.

point at which the two curves cross is rather different in each, and the difference between the temperatures read off from the curves for any date is not always the same. But no certain relationship between these temperature fluctuations and the fishery fluctuations can be deduced. There *ought* to be some relationship, and the fact that it cannot be seen is not to be explained in any other way than by supposing that the hypothesis of temperature-adaptation by migration is not true, or that the temperature data, and the fishery statistics, are too inaccurate to exhibit it.

The years 1909 and 1910 were years of low range of temperature at Nelson Buoy: the latter was 12·5° in 1909 and 12·1° in 1910. These also were years in which the plaice fishery in Red Wharf Bay was relatively good. The years 1911 and 1912 were years in which the range of temperature was high: it was 14·25° in the former and 13·0° in the latter, and they were also years in which the fishery in Red Wharf Bay was relatively poor.

In fig. 5 the fluctuations of temperature at hydrographic Stations 5, 6 and 7, in the month of November, are compared with the mean daily catch of plaice, in cwts., in the Red Wharf Bay area during the last two months of the year. Here there does seem to be a relationship. The years of low temperature are good fishery years, and *vice versa*, and the correspondence is quite good—indeed, it is all that could be desired—except for the year 1912. In that year the catch of plaice ought to have been better than that of 1911, since the temperature had fallen, yet the opposite is the case. If, however, we suppose—what, indeed, is very probably the case—that the exceptionally bad weather of the latter part of 1912 affected the fishing by preventing the smacks from going to sea, then the relationship would hold good.

There can be no doubt that the experimental work does indicate with a fair degree of certainty that fluctuations in the abundance of fish on a ground are the result of fluctuations in the regular migrations on to that ground; and also that these migrations are affected by temperature-fluctuations, with regard to the number of fish taking part in them and the dates at which the migrations begin and end. The fact that the physical and statistical data available fail to show this relationship in a satisfactory manner is, no doubt, due only to the inaccuracies, or insufficiency, of both these series of data. The methods in use, both with regard to the physical observations and the collection of the fishery statistics, are quite satisfactory: the *planning* of the



TEXT-FIG. 5. Variations in the catch of plaice per day's fishing, and in the sea-temperature in November at hydrographic stations 5, 6 and 7. The mean in each case is 100, the other figures represent the deviation above and below these means.

work is, perhaps, nearly all that can be desired. But it is quite clear that this work is not carried out with the thoroughness that is necessary for the complete demonstration of the relationships sought, apart altogether from the possibility of the prediction of the productivity of a fishery. This is the main result of a study of the physical and statistical data obtained in a relatively small sea-area, where the observations are probably more numerous than almost anywhere else in the British Seas. It has not, so far, been realised that fishery investigations of this kind ought to be conducted with all the thoroughness and attention to detail, and the desire to avoid all possible sources of error, that characterise a laboratory investigation in chemical and physical science. Of course the great scale on which a fishery investigation must be carried on makes this accuracy difficult of attainment, yet it is quite certain, from a study of the data considered above, that without it much of the labour expended must be futile.

I.—Sea-temperatures at the Light-Vessels, 1912. Monthly Means.

	Carnarvon Bay, 53° 6′ N. 4° 45′ W.	Liverpool N'rth-west, 53° 31′ N. 3° 31′ W.	Morecambe Bay, 53° 54′ N. 3° 31′ W.	Bahama Bank, 54° 20′ N. 4° 13′ W.	Solway, 54° 48′ N. 3° 32′ W.
January	8·94	7·49	6·16	7·33	5·40
February	8·21	5·93	4·93	6·11	4·86
March	8·21	6·83	6·72	7·49	7·11
April	9·04	8·83	8·61	8·66	9·49
May	10·91	11·17	11·99	11·01	11·72
June	12·16	13·49	13·60	12·94	13·89
July	14·44	15·26	15·94	14·65	16·43
August	14·82	15·05	14·77	14·60	14·38
September	14·15	13·77	13·49	13·49	13·06
October	12·94	11·93	10·96	12·04	10·23
November	11·38	9·44	8·50	10·06	7·72
December	10·29	8·27	7·33	8·38	6·21

II. Mean Sea-temperatures at various Coastal Stations in 1911-1912.

Month.	Piel Gas Buoy, 54° 1′ N. 3° 12′ W.			Off Blackpool, 53° 50′ N. 3° 5′ W.			Nelson Buoy, 53° 43′ N. 3° 12′ W.			Liverpool Bar, 53° 43′ N. 3° 12′ W.			Great Orme's Hd. 53° 21′ N. ? 3° 53′ W.			Red Wharf Bay, 53° 22′ N. 4° 5′ W.		
	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.
1911																		
January	2	31	4·7	6	3-26	4·8	3	19-26	4·8	2	25-26	5·35	7	3-23	5·74	5	4-24	6·52
February	1	1	4·6	7	2-16	3·44	2	2-15	4·35	—	—	—	1	13	5·0	—	—	—
March	6	20-29	5·6	1	14	5·7	—	—	—	—	—	—	1	14	6·4	—	—	—
April	5	5-26	6·16	2	11-13	6·3	3	15-21	6·47	2	19-21	7·10	2	19-25	7·4	3	19-20	6·7
May	5	1-11	9·46	1	27	13·4	1	27	13·0	—	—	—	1	27	12·2	—	—	—
June	3	12-14	13·47	5	14-29	13·76	3	14-29	14·45	—	—	—	3	1-19	13·23	3	14-19	13·2
July	—	—	—	7	1-12	15·41	2	14-18	17·0	2	17-18	16·9	6	6-27	16·3	2	4-17	13·85
August	—	—	—	14	7-31	18·44	8	7-31	18·62	9	14-30	18·4	16	8-31	17·47	6	8-29	16·78
September	3	6-13	16·66	8	9-27	15·60	6	10-27	15·75	5	9-20	17·8	9	9-26	15·99	2	19-20	15·45
October	2	4-24	12·7	14	2-29	11·71	9	4-31	12·06	1	31	13·1	7	3-29	12·43	4	19-31	12·2
November	—	—	—	4	25-30	6·20	1	29	6·50	1	28	6·5	6	1-30	7·68	3	1-27	8·73
December	—	—	—	3	9-27	5·80	—	—	—	1	13	6·8	19	1-29	7·40	6	1-19	7·9
1912																		
January	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February	1	13	4·2	3	10-24	4·2	3	9-16	3·4	2	9-16	3·8	2	6-9	4·7	—	—	—
March	4	11-18	6·15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
April	5	10-29	8·00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May	4	6-14	10·30	2	22-29	11·85	7	9-31	12·30	1	24	11·8	1	30	12·4	1	30	11·6
June	2	3-6	11·45	3	6-12	13·03	2	5-10	13·05	—	—	—	3	5-12	13·13	3	4-12	12·8
July	3	1-31	15·27	5	16-26	16·94	7	10-26	16·44	6	15-26	16·47	5	4-25	15·2	2	23	15·2
August	—	—	—	9	6-30	14·53	8	6-30	14·91	5	6-27	14·84	6	8-25	14·73	5	15-23	14·32
September	1	10	13·2	5	17-27	12·7	8	13-28	12·47	4	13-28	12·60	9	13-28	13·08	—	—	—
October	4	7-23	10·9	7	1-25	10·60	4	1-25	10·80	3	10-25	10·90	15	1-28	11·5	4	1-16	12·2
November	4	4-19	8·6	4	15-23	8·20	4	14-23	8·57	1	23	8·40	6	13-27	8·75	6	21-27	9·1
December	1	3	6·5	8	6-27	6·04	1	6	6·60	1	11	6·3	16	5-28	8·26	9	5-27	8·63

III. Mean Sea-temperatures at various Coastal Stations in 1911-1912.

Month.	Point Lynus. 53° 26′ N. 4° 17′ W.			Middle Mouse. 53° 27′ N. 4° 26′ W.			Carmel Head. 53° 24′ N. 4° 35′ W.			South Stack. 53° 18′ N. 4° 43′ W.			Bardsey Island. 52° 47′ N. 4° 47′ W.			Near New Quay Head. 52° 15′ N. 4° 25′ W.		
	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.	Observns.	Range.	Temp.
1911																		
January	3	3-18	6·66	2	16-18	6·7	2	16-18	6·9	2	16-17	7·35	2	16-17	7·0	1	17	6·3
February	3	2-15	6·46	2	2-15	6·7	1	15	6·6	1	14	6·8	—	—	—	—	—	—
March	—	—	—	—	—	—	1	16	6·7	1	15	6·8	—	—	—	—	—	—
April	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—	—	—	1	29	10·7	3	30-31	13·57
June	4	1-19	13·27	4	6-19	12·02	4	1-19	11·77	3	1-19	11·62	5	1-18	11·8	4	17-18	14·25
July	3	4-17	13·77	2	12-17	14·25	2	12-17	14·1	3	13-16	13·8	2	15-16	14·0	—	—	—
August	5	3-30	16·26	5	3-30	16·24	4	3-30	15·95	4	3-29	15·9	2	9-10	16·0	2	9	17·55
September	6	10-25	15·68	6	10-25	15·58	6	10-25	15·48	6	10-24	15·35	2	24	15·0	—	—	—
October	7	9-31	12·44	6	9-31	10·95	6	10-31	12·91	5	10-25	13·32	4	10-18	13·35	1	10	13·7
November	2	26-27	7·70	2	26-27	8·20	1	26	8·8	—	—	—	—	—	—	—	—	—
December	11	1-21	8·01	9	1-21	8·39	9	1-21	8·91	3	2-12	8·96	—	—	—	—	—	—
1912																		
January	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February	5	6-29	6·2	2	9-29	6·55	2	9-29	7·2	4	7-27	7·05	5	7-27	6·92	5	9-27	7·02
March	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
April	1	8	9·4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May	—	—	—	1	3	9·6	1	3	9·7	—	—	—	—	—	—	—	—	—
June	3	4-12	11·4	2	10-12	11·17	2	10-12	11·8	2	11-12	11·9	2	11-12	12·2	1	11	14·6
July	5	4-25	14·36	4	4-25	14·4	5	4-25	14·32	8	2-25	13·84	6	3-25	14·07	4	4-24	16·32
August	4	9-25	14·42	8	9-25	14·4	4	9-25	14·4	4	9-25	14·35	4	13-25	14·65	1	24	15·60
September	6	13-28	13·3	4	13-28	13·6	4	13-28	13·77	8	11-30	13·81	8	12-30	13·32	1	30	13·60
October	11	1-28	11·9	6	1-28	12·3	6	1-28	12·4	12	1-27	12·50	3	8-26	12·7	1	8	12·80
November	4	6-27	9·9	3	6-27	10·5	3	6-27	10·5	4	5-25	11·05	2	24-25	10·2	—	—	—
December	5	5-28	8·59	3	5-13	8·8	3	5-13	9·1	5	5-12	9·08	2	10-12	9·5	3	10-11	9·00

IV.—Mean Monthly Sea-temperatures at various Coastal Stations in 1909-1912.

	Point Lynus.	Red Wharf Bay.	Great Orme's Head.	Liverpool Bar.	Nelson Buoy.	Piel Gas Buoy.
January	6·5	7·5	6·3	5·6	4·8	5·1
February	6·1	6·3	5·4	4·4	3·8	4·4
March	5·1	5·7	5·6	4·7	4·6	5·4
April	7·7	7·1	7·3	7·2	7·3	7·2
May	8·8	10·3	11·2	11·8	12·0	9·3
June	11·8	12·6	12·9	15·6	13·5	12·0
July	13·7	14·5	15·4	16·2	15·9	14·8
August	14·9	15·6	15·9	16·3	16·4	—
September	14·4	15·0	14·5	14·9	14·2	14·6
October	12·5	12·5	12·3	12·5	12·1	12·7
November	9·3	8·8	8·2	7·6	7·6	8·9
December	8·4	8·2	7·4	6·6	6·4	6·5

IVa.—Mean Sea-temperatures at the Nelson Buoy and Red Wharf Bay Fishing Grounds.

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
	Nelson Buoy—Liverpool Bar.					
1909	16·0	13·9	13·2	7·5	5·9	5·2
1910	15·8	14·9	12·7	6·9	6·7	5·1
1911	18·5	16·8	12·6	6·5	6·8	—
1912	14·9	12·5	10·8	8·5	6·4	—
	Point Lynus—Red Wharf Bay—Gt. Orme's Head.					
1909	15·5	14·3	13·6	9·2	7·7	6·9
1910	14·8	14·6	11·8	8·4	8·1	6·3
1911	16·8	15·7	12·3	8·0	7·8	6·4
1912	14·5	13·2	11·9	9·2	8·5	—

V.—Dates on which hydrographic stations 5, 6 and 7 were investigated, 1906 to 1912.

Cruise.	1906	1907	1908	1909	1910	1911	1912
Feb. ...	—	18-II	25-II	27-I	2-II	1-II	14-II
May ...	—	7-V	14-V	18-V	3-V	—	7-V
Aug. ...	—	29-VII	27-VII	27-VII	9-VIII	—	30-VII
Nov. ...	14-XI	5-XI	27-X	4-XI	25-X	25-X	8-XI

VI.—Rate of variation per day of Sea-temperature at Carnarvon Bay Light-Vessel during the range of dates of the hydrographic cruises in 1906 to 1912.

February	$\frac{\delta_t^{\circ}}{\delta_t}$ = 0·0102, decreasing
May	,, = 0·081, increasing
August	,, = 0·0033, increasing
November	,, = 0·038, decreasing

VII.—Mean differences of Sea-temperature at the hydrographic stations 5, 6 and 7, 1907—1912.

	Mean Temp. at Station 5.	Mean Temp. at Station 6.	Mean Temp. at Station 7.
February	T° + ·01	T°	T° — ·33
May	T° — ·09	T°	T° + ·05
August	T° + ·08	T°	T° + ·63
November...........	T° — ·29	T°	T° + ·03

VIII.—Mean differences between the Sea-temperature at surface and bottom at hydrographic stations 5, 6, and 7, 1907—1912.

	Station 5		Station 6		Station 7	
	Temp. at Surface.	Temp. at Bottom.	Temp. at Surface.	Temp. at Bottom.	Temp. at Surface.	Temp. at Bottom.
February ...	T°	T° — 0·12	T°	T° — 0·08	T°	T° — 0·05
May	T°	T° — 0·18	T°	T° — 0·29	T°	T° — 0·16
August	T°	T° — 0·40	T°	T° — 0·20	T°	T° — 0·30
November ...	T°	T° — 0·11	T°	T° — 0·15	T°	T° — 0·04

IX.—Average temperatures at various stations during the years 1909—1912.

	Feb.	May.	Aug.	Nov.	Mean Annual Range.
Hydrographic Station 1 ...	4·9	9·3	15·3	11·5	10·4
,, ,, 2 ...	5·4	8·9	14·3	11·6	8·9
,, ,, 3 ...	6·2	8·6	13·8	11·8	7·6
,, ,, 4 ...	6·7	8·6	13·4	12·0	6·7
,, ,, 5 ...	7·5	8·5	12·9	12·1	5·4
,, ,, 6 ...	7·6	8·4	13·1	12·3	5·5
,, ,, 7 ...	7·3	8·4	13·8	12·3	6·5
Piel Gas Buoy	4·4	9·3	—	8·9	—
Nelson Buoy	3·8	12·0	16·4	7·6	12·6
Liverpool Bar	4·4	11·8	16·3	7·6	11·9
Great Orme's Head	5·4	11·2	15·9	8·2	10·5
Red Wharf Bay	6·3	10·3	15·6	8·8	9·3
Point Lynus	6·1	8·8	14·9	9·3	8·8
Morecambe Bay Lightship	4·8	10·8	16·0	9·0	11·2
Liverpool N.W. Lightship	5·6	10·4	15·3	9·3	9·7

X.—Mean Sea-temperatures at hydrographic stations 5, 6 and 7.

	15 February.		15 May.		15 August.		15 November.	
	Mean Temp.	Correct'd Temp.	Mean Temp.	Correct'd Temp.	Mean Temp.	Correct'd Temp.	Mean Temp.	Correct'd Temp.
1906......	—	—	—	—	—	—	11·70	11·66
1907......	7·07	7·11	7·95	8·59	12·43	12·49	12·52	12·14
1908......	7·14	7·25	8·28	8·33	12·99	13·05	13·13	12·45
1909......	8·25	8·07	8·58	8·34	12·77	12·83	11·93	11·51
1910......	6·85	6·73	7·69	8·66	13·50	13·52	12·10	11·34
1911......	7·57	7·46	—	(8·46)	—	(15·37)	13·11	12·35
1912......	7·08	7·08	9·24	9·88	13·49	13·54	12·06	11·79

The numbers in brackets are calculated as explained in the text.

XI.—Average catch of plaice (in cwts.) per day's fishing during the period 1907—1912. Red Wharf Bay and Channel Course.

Week.	Average Catch.	Week.	Average Catch.	Week.	Average Catch.	Week.	Average Catch.
1	1·50	14	0·01	27	0·31	40	1·36
2	1·26	15	0·04	28	0·45	41	1·47
3	0·80	16	0·19	29	0·53	42	1·54
4	0·26	17	0·15	30	0·46	43	1·27
5	0	18	0·15	31	0·68	44	1·10
6	0·20	19	0·11	32	0·36	45	1·20
7	0·13	20	0	33	0·96	46	2·53
8	0·43	21	0·07	34	0·79	47	2·31
9	0	22	0·08	35	0·67	48	3·05
10	0·10	23	0·01	36	1·09	49	3·57
11	0·05	24	0·06	37	0·72	50	5·24
12	0·09	25	0·12	38	0·88	51	5·29
13	0·06	26	0·05	39	0·87	52	1·57

XII.—Average catch of plaice (in cwts.) per day's fishing during each of the years 1907—1912. Red Wharf Bay and Channel Course.

4 Weekly Periods.	1907	1908	1909	1910	1911	1912	Mean 1907-12
1	0	0·03	0·13	3·68	0·58	0	0·88
2	0	0·06	0·07	0·79	0·02	0	0·18
3	0	0	0	0·23	0·01	0·06	0·06
4	0·20	0	0·04	0·12	0·02	0	0·08
5	0·14	0	0·02	0·25	0	0	0·08
6	0·19	0	0·03	0·15	0·02	0	0·08
7	0·35	0·02	0·04	0·26	0·20	0·44	0·26
8	0·38	0·03	0·75	0·75	0·72	0·20	0·57
9	0·43	0·26	0·92	0·71	0·55	1·28	0·83
10	0·42	1·26	1·28	0·53	0·29	1·00	0·96
11	0·82	0·18	1·99	0·94	0·99	1·81	1·35
12	0·82	0·89	1·96	2·78	3·20	1·72	2·27
13	2·87	1·66	3·07	7·01	2·42	0·91	3·59

XIII. Average daily catches (in cwts.) of Plaice on the Red Wharf Bay-Channel Course Winter Fishing Grounds, per week during the years 1907-1912.

Week.	1907.			1908.			1909.			1910.			1911.			1912.		
	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.
1	1	0	0	4	0	0	1	0	0	3	13·25	4·42	3	4·75	1·58	0	0	0
2	43	0	0	20	2	0·10	20	6	0·30	7	38	5·43	26	13	0·50	0	0	0
3	77	0	0	36	0·25	0·01	18	3·75	0·21	56	213	3·80	21	0	0	0	0	0
4	53	0	0	51	0	0	0	0	0	30	32·75	1·09	18	4·25	0·23	10	0	0
5	28	0	0	11	0	0	26	0	0	4	0	0	46	0	0	7	0	0
6	24	0	0	14	3·25	0·23	20	6	0·30	40	19·75	0·49	43	0	0	1	0	0
7	14	0	0	4	0	0	5	0	0	35	18·5	0·56	19	1·5	0·08	8	0	0
8	18	0	0	0	0	0	0	0	0	7	15	2·14	0	0	0	16	0	0
9	15	0	0	0	0	0	11	0	0	7	0	0	0	0	0	3	0	0
10	8	0	0	7	0	0	4	0	0	12	3	0·25	17	0	0	4	1	0·25
11	7	0	0	1	0	0	6	0	0	38	7·75	0·20	19	1	0·05	8	0	0
12	1	0	0	30	0	0	31	0	0	17	8	0·47	9	0	0	5	0	0
13	8	1·5	0·18	26	0	0	14	0	0	10	1	0·10	3	0	0	0	0	0
14	0	0	0	6	0	0	19	0·5	0·03	4	0	0	12	0·5	0·04	7	0	0
15	19	0	0	0	0	0	11	0	0	7	1	0·14	4	0·25	0·06	0	0	0
16	13	8	0·61	0	0	0	8	1	0·12	2	0·5	0·25	0	0	0	38	0	0
17	4	2	0·50	0	0	0	16	0	0	6	1·5	0·25	9	0	0	3	0	0
18	17	0	0	0	0	0	20	0	0	4	3	0·75	4	0	0	8	0	0
19	1	0·5	0·5	10	0	0	15	1	0·07	0	0	0	17	0	0	0	0	0
20	4	0	0	0	0	0	14	0	0	21	0	0	9	0	0	20	0	0

Table XIII—*Continued*

Week.	1907.			1908.			1909.			1910.			1911.			1912.		
	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.
21	5	1	0·2	5	0	0	18	0	0	3	0·5	0·16	8	0	0	0	0	0
22	12	1·5	0·12	4	0	0	15	0·25	0·01	17	2·5	0·15	10	1	0·10	0	0	0
23	7	0	0	26	0	0	6	0·25	0·04	0	0	0	0	0	0	0	0	0
24	17	7·5	0·44	5	0	0	19	1·5	0·08	9	2·5	0·28	0	0	0	0	0	0
25	3	1	0·33	10	1	0·1	0	0	0	0	0	0	4	0	0	11	2	0·18
26	2	1	0·5	4	0	0	0	0	0	6	0	0	1	0·25	0·25	4	0·5	0·12
27	6	1	0·16	16	0	0	0	0	0	3	1·5	0·50	8	1·25	0·16	7	5	0·71
28	5	2	0·4	6	0	0	3	0·5	0·16	13	2	0·54	9	3·5	0·39	4	3	0·75
29	3	3	1	8	0	0	4	2	0·50	0	0	0	3	2	0·66	2	1	0·50
30	10	4·25	0·42	16	2	0·12	16	13.0	0·81	18	6	0·33	9	3	0·33	4	1·25	0·31
31	6	0	0	1	0	0	32	28	0·87	15	25	1·66	9	8	0·88	0	0	0
32	3	0	0	2	0	0	48	40	0·83	9	9	1·0	3	3	1·0	0	0	0
33	9	5	0·55	1	1·5	1·5	38	21	0·55	1	0·25	0·25	0	0	0	3	6	2
34	0	0	0	15	6·25	0·41	16	20·25	1·26	13	9	0·69	6	1	0·16	18	26·5	1·42
35	9	6	0·66	7	0	0	6	3	0·50	14	11·5	0·81	5	2·75	0·55	14	11·75	0·82
36	7	3·5	0·5	25	3·75	0·15	19	26	1·37	11	12	1·09	5	7·5	1·50	8	7	0·87
37	11	5	0·45	34	41·75	1·22	10	13·25	1·32	15	9	0·60	0	0	0	0	0	0
38	6	1	0·16	15	18·0	1·20	6	8	1·33	2	0·75	0·37	9	5·5	0·61	12	9	0·75
39	10	6·75	0·67	22	14	0·63	21	17·5	0·83	8	2·5	0·31	6	2	0·33	32	50	1·56
40	14	5·5	0·39	20	40	2·00	25	42	1·64	7	6	0·86	2	0·5	0·25	16	27	1·69

Table XIII—*Continued*

Week.	1907.			1908.			1909.			1910.			1911.			1912.		
	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.	No. of days fishing.	Fish caught.	Average per day.
41	22	16·75	0·76	31	13·0	0·42	33	86	2·61	32	24	0·75	8	6·5	0·81	3	6	2·00
42	38	21	0·55	16	0	0	57	146·5	2·57	15	9	0·60	8	9	1·10	10	29	2·90
43	47	25·25	0·54	13	0	0	49	115·5	2·35	5	4·5	0·90	38	26	0·68	15	28·5	1·90
44	14	20	1·43	21	6·5	0·31	22	1	0·45	15	22·5	1·50	33	45·75	1·38	68	30·5	0·45
45	8	0	0	41	19·5	0·47	18	26	1·50	7	5	0·71	20	56·5	2·80	40	22	0·55
46	44	19·75	0·45	37	63·5	1·71	19	47·5	2·50	33	81	2·45	30	131	4·40	56	63	1·12
47	73	75·75	1·03	50	47·5	0·95	9	26·5	2·94	46	81·7	1·77	28	47	1·70	62	196	3·16
48	84	152·5	1·81	20	7·0	0·35	10	9	0·90	65	403·5	6·20	57	224·25	3·90	45	93	2·07
49	137	333	2·43	90	78·0	0·87	65	95	1·44	100	535·5	5·35	99	546·5	5·50	90	115	1·27
50	98	309·25	3·05	90	131·0	1·45	26	167·5	6·52	50	617·5	12·35	66	104·45	1·60	64	79·5	1·24
51	77	332	4·31	86	251·5	2·92	62	270·5	4·36	75	921·5	12·29	30	66·5	2·2	42	17	0·40
52	21	36	1·71	47	67·0	1·42	28	7·25	0·26	23	85	3·70	0	0	0	4	3	0·75
53	—	—	—	—	—	—	1	2·75	2·75	2	2·75	1·37	—	—	—	—	—	—

REPORT ON HYDROGRAPHIC OBSERVATIONS MADE IN THE IRISH SEA DURING 1912.

By Henry Bassett, Jun., D.Sc.,
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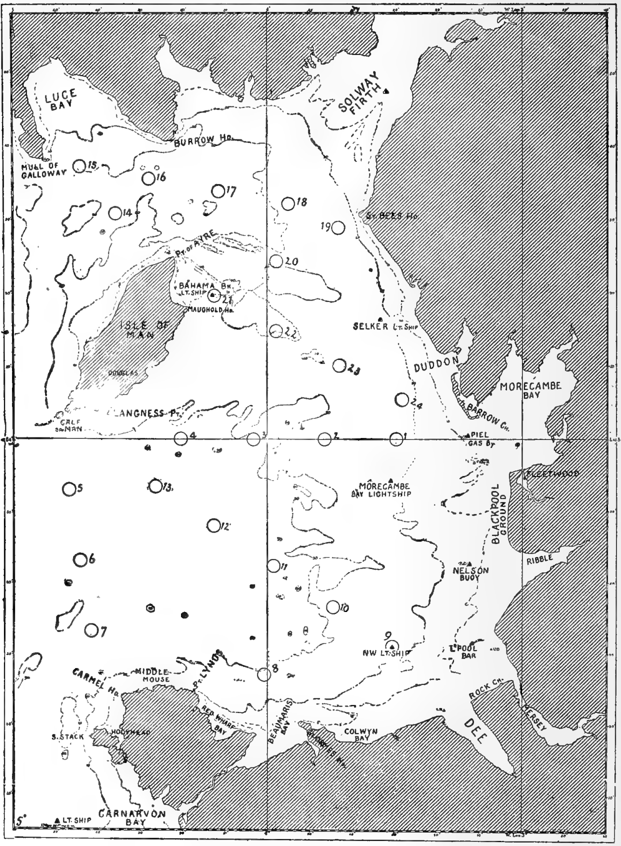
It is pleasant to be able to report that, thanks to a grant from the Development Commissioners, the hydrographic investigations which the Lancashire and Western Sea Fisheries Committee have been carrying out for the past seven years have now been put on a much firmer basis. It has become possible to make observations monthly instead of only quarterly, and the S.S. "James Fletcher," under Captain Wignall's able guidance, now makes the necessary cruises as part of the regular routine. The monthly cruises under the new régime began in May, 1912, since which date Mr. W. Riddell has taken over the actual collection of the water samples and all necessary observations on the steamer. The samples are forwarded to Reading for analysis.

The number of Stations at which observations are made has been increased to 24, with the object of making a more detailed study of the area than has hitherto been possible. The positions of the Stations are shown on the accompanying chart. Surface observations are made at all these Stations on the February, May, August and November, or "quarterly," cruises. Bottom and intermediate samples are only collected from the three deep Stations V, VI and VII, since such samples from the shallow Stations are of relatively little value, owing to the fact that there the water either has the same salinity from top to bottom or else shows erratic



Observation Stations in 1912.

variations due to tidal disturbances.* On the remaining monthly cruises observations are only made at Stations I to VII. It is thought that the monthly observations at Stations V, VI and VII will prove of considerable utility in connection with weather forecasting. I have insisted upon this in several former reports, and more recently in a paper communicated to the Royal Meteorological Society.†

The hydrographic observations made during 1912 are given in the tables which follow. The most striking feature about them is the very high salinities which have prevailed throughout the year. We have never found such salt water in this portion of the Irish Sea since we began observations in 1906. This applies especially to Stations V, VI and VII, but also to Stations III and IV. How is this increase in the salinities to be accounted for?

The annual variations in the salinities at Stations V, VI and VII found in former years have hitherto in these reports been regarded as indicating variations in the strength of the Gulf Stream Drift. In years when the Drift is strong higher salinities are found at these Stations in the winter and spring months than in years when it is less marked.

There is every reason for thinking that this explanation is on the whole correct, but at the same time I consider that the conditions prevailing during the last year have been quite exceptional, and that the high salinities were not due to an unusually strong Gulf Stream Drift, as might be at first supposed, but to an entirely different cause.

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* See *Lanc. Fish. Lab. Reports,* No. XV, p. 76 (1907) and No. XVI, p. 57 (1908).

† *Quart. Journ. Roy. Met. Soc.,* XXXIX, 43 (1913).

This cause seems to have been the flooding of the English Channel and Irish Sea by water of Mediterranean origin. It is well known that a current of water of high salinity flows from the Mediterranean through the Straits of Gibraltar below the inflowing current of Atlantic water.

It was shown by Professor H. N. Dickson,* from the results of cruises made by Dr. Wolfenden in 1903-1905, that this Mediterranean water spreads westwards and northwards at a depth of between about 500 and 1,000 metres below the less salt and specifically lighter Atlantic water. His figures, and those of the German "Planet" (1906) and Danish "Thor" (1904-1905)† expeditions, show that the Mediterranean water can be traced outside the Continental shelf as far North as about Latitude 53°.

Dickson also suggested that this Mediterranean water might sometimes rise to the surface and enter the English Channel. This is just what seems to have happened during 1912.

In my paper to the Royal Meteorological Society already referred to, I have pointed out that the oceanic circulation in the North Atlantic is composed of two main circulations—one centred about the Sargasso Sea, with the Gulf Stream forming its north-western portion; the other centred about Iceland and fringing the Arctic regions, with the Labrador Current forming its western section.

The Gulf Stream Drift is, so to say, a composite current partly derived from the southern circulation and partly from the northern.

The southern and northern circulations are probably largely independent of one another and can vary in

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* *Memoirs of the Challenger Society*, No. 1, p. 107 (1909).

† Krümmel. *Handbuch der Oceanographie*, Vol. II, p. 616.

vigour independently, and such variations will naturally affect the character of the composite Gulf Stream Drift.

Four chief cases can be anticipated according as either one or both of the circulations are strong or weak :—

(*a*) Southern circulation (and Gulf Stream) strong; northern circulation (and Labrador Current) strong.
(*b*) Southern circulation weak; northern circulation weak.
(*c*) Southern circulation strong; northern circulation weak.
(*d*) Southern circulation weak; northern circulation strong.

I consider that to each of the above four types of oceanic circulation correspond definite meteorological conditions, and that the latter, in so far as they affect the succeeding summer can be foreseen from the value and time of occurrence of the maximum salinities—especially on the line Holyhead—Calf of Man—in the Irish Sea.

Type (*a*) will probably be the most general. There will be a maximum salinity on the line Holyhead—Calf of Man of about 34·4 in February. This type will probably be associated with the usual kind of somewhat variable English summer. The conditions during 1907 and 1908 seem to have corresponded to this type.

When the oceanic circulation is of type (*b*) less water of high salinity reaches our shores from the Atlantic, so that a salinity maximum of only about 34·2 is reached (on Holyhead—Calf line), and that not before May. The years 1909 and 1910, with their dismal summers characterised by little sunshine and much rain (but not an excessive amount), are typical of what may be expected in such cases.

An early salinity maximum of somewhat over 34·4 in December succeeded by a magnificent summer like that of 1911 in the following year seems to result from the third type of circulation. And lastly, when the oceanic circulation is of type (*d*) the Gulf Stream Drift water is sufficiently cold to be heavier than the salter water of Mediterranean origin which normally flows northwards below it. The salter water consequently rises to the surface and enters the English Channel and Irish Sea, leading to a salinity maximum of about 34·6 on the line Holyhead—Calf of Man in February. In spite of the high salinities in the Irish Sea the conditions in the Atlantic are probably more unfavourable from the meteorological point of view than even those corresponding to type (*b*). The type of summer experienced in 1912 with an excessive rainfall—often of a thundery character—appears in fact to be associated with hydrographic conditions of this nature.

It may be mentioned that a number of southern forms not usually found in the plankton of the Irish Sea were noticed during 1912. Large numbers of the "Portuguese man-of-war" (*Caravella* sp.) were taken in the English Channel*, and I even found one on the shore of Carnarvonshire, near Criccieth, on April 5th. The presence of such southern forms, though not proving the entry of Mediterranean water into our area, is, nevertheless, quite intelligible on such a supposition.

Our observations for January, February and March, 1913, again show very high salinities, as can be seen from the following figures for Stations V, VI and VII:—

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* Also in Feb. (*Nature*, Feb. 27) and Mar., 1913.

Station	Surface salinities		
	Jan.	Feb.	Mar.
V.	34·29	34·52	34·56
VI.	34·38	34·56	34·45
VII.	34·31	34·16	34·45

These salinities seem to indicate hydrographic conditions in the North Atlantic for 1913 similar to those prevailing during 1912. It is to be feared, therefore, that the meteorological outlook for the coming summer is distinctly gloomy, and that a repetition of the bad weather of 1912 may be anticipated.

In the following tables the deepest samples from Stations V, VI and VII were always taken from within one or two metres of the bottom. The different depths found at these Stations on different occasions are due to the fact that there are several small depressions in the bed of the sea near the Stations, so that a very small difference in the position may make a considerable difference in the depth of water found.

February 14, 1912.

Stations V. to VII. Surface observations only.

Station.	Time.	T°	Cl°/oo	S°/oo	σ_t
V. 53°53′N.; 4°46′W.	11.30 a.m.	7·4	19·18	34·65	27·11
VI. 53°43′N.; 4°44′W.	12.30 p.m.	7·2	19·08	34·47	27·00
VII. 53°33′N.; 4°41′W.	1.30 p.m.	6·8	19·03	34·38	26·99

May 7-10, 1912.

Stations I. to IV., 7/5/12. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54° N.; 3° 30′ W.	10.40 a.m.	9·6	18·42	33·28	25·71
II.	54° N.; 3° 47′ W.	11.40 a.m.	8·95	18·54	33·49	25·96
III.	54° N.; 4° 4′ W.	12.40 p.m.	9·1	18·77	33·91	26·27
IV.	54° N.; 4° 20′ W.	1.40 p.m.	9·1	19·04	34·40	26·65

Station V. 53° 53′ N.; 4° 46′ W. 7/5/12 (3.30 p.m.),

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	9·27	19·09	34·49	26·69
28	9·0	19·09	34·49	26·73
57	9·0	19·09	34·49	26·73

Station VI., 53° 43′ N.; 4° 44′ W. 7/5/12 (4.50 p.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	9·35	19·12	34·54	26·73
30	9·0	19·13	34·56	26·79
70	8·9	19·14	34·58	26·83

Station VII., 53° 33′ N.; 4° 41′ W. 7/5/12 (6 p.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	9·3	19·08	34·47	26·68
30	9·0	19·06	34·43	26·69

A bottom sample (70 metres) was not taken.

Stations VIII to XXIV. Surface observations only.

Station.		Date and Time.		T°	Cl°/oo	S°/oo	σ_t
VIII.	53°27′N. ; 4°5′W.	8.5.12	a.m. 11.0	9·4	18·74	33·86	26·18
IX.	53°31′N. ; 3°31′W.	8.5.12	p.m. 12.23	9·6	18·21	32·90	25·39
X.	53°37′N. ; 3°45′W.	8.5.12	1.23	9·2	18·64	33·68	26·07
XI.	53°43′N. ; 3°58′W.	8.5.12	2.20	9·2	18·70	33·78	26·16
XII.	53°48′N. ; 4°12′W.	8.5.12	3.20	9·0	19·04	34·40	26·67
XIII.	53°54′N. ; 4°27′W.	8.5.12	4.15	9·0	19·10	34·51	26·75
XIV.	54°32′N. ; 4°37′W.	9.5.12	a.m. 9.20	9·35	18·78	33·93	26·05
XV.	54°37′N. ; 4°45′W.	9.5.12	10.5	9·35	18·68	33·75	26·11
XVI.	54°35′N. ; 4°27′W.	9.5.12	11.0	9·8	18·36	33·17	25·59
XVII.	54°34′N. ; 4°12′W.	9.5.12	noon	9·75	18·74	33·86	26·12
XVIII.	54°32′N. ; 3°55′W.	9.5.12	p.m. 2.0	9·6	18·71	33·80	26·10
XIX.	54°29′N. ; 3°43′W.	9.5.12	2.50	10·4	18·32	33·10	25·42
XX.	54°24′N. ; 3°57′W.	9.5.12	3.50	10·2	18·66	33·71	26·94
XXI.	54°20′N. ; 4°13′W.	9.5.12	6.20	10·0	18·89	34·13	26·29
XXII.	54°15′N. ; 3°57′W.	10.5.12	a.m. 9.0	9·8	18·55	33·51	25·85
XXIII.	54°10′N. ; 3°42′W.	10.5.12	10.0	9·4	18·41	33·26	25·71
XXIV.	54°5′N. ; 3°27′W.	10.5.12	11.0	10·1	18·19	32·86	25·28

June 3 to 4, 1912.

Stations I to IV., 3/6/12. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54° N. ; 3° 30′ W.	4.0 p.m.	11·4	18·33	33·12	25·26
II.	54° N. ; 3° 47′ W.	6.0 p.m.	11·4	18·32	33·10	25·24
III.	54° N. ; 4° 4′ W.	6.55 p.m.	11·6	18·70	33·78	25·74
IV.	54° N. ; 4° 20′ W.	7.55 p.m.	10·5	18·90	34·14	26·22

Station V., 53° 53′ N. ; 4° 46′ W. 4/6/12 (10 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·4	19·10	34·51	26·52
30	10·15	19·08	34·47	26·53
100	10·2	19·10	34·51	26.55

Station VI., 53° 43′ N.; 4° 44′ W. 4/6/12 (11.15 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·2	19·10	34·51	26·55
30	10·1	19·09	34·49	26·55
68	10·1	19·09	34·49	26·55

Station VII., 53° 33′ N.; 4° 41′ W. 4/6/12 (12.30 p.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·45	19·06	34·43	26·46
30	10·4	19·06	34·43	26·46
74	10·4	19·06	34·43	26·46

July 1 to 2, 1912.

Stations I. to IV., 1/7/12. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N.; 3°30′W.	2.0 p.m.	14·2	18·36	33·17	24·75
II.	54°N.; 3°47′W.	3.45 p.m.	14·3	18·41	33·26	24·80
III.	54°N.; 4°4′W.	4.45 p.m.	13·6	18·60	33·60	25·21
IV.	54°N.; 4°20′W.	5.45 p.m.	12·6	18·99	34·31	25·96

Station V., 53° 53′ N.; 4° 46′ W. 2/7/12 (10 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	12·4	19·03	34·38	26·05
30	12·2	—	—	—
62	12·2	19·03	34·38	26·09

Station VI., 53° 43′ N.; 4° 44′ W. 2/7/12 (11 a.m.)

Depth (metres)	T°	$Cl°/_{oo}$	$S°/_{oo}$	σ_t
0	12·45	19·04	34·40	26·05
30	12·2	19·04	34·40	26·10
69	12·2	19·03	34·38	26·09

Station VII., 53° 33′ N.; 4° 41′ W. 2/7/12 (12 noon.)

Depth (metres)	T°	$Cl°/_{oo}$	$S°/_{oo}$	σ_t
0	12·73	19·03	34·38	26·12
30	12·5	—	—	—
73	12·5	19·02	34·36	26·10

July 29-31, 1912.

Stations I. to IV., 29/7/12. Surface observations only.

Station.		Time.	T°	$Cl°/_{oo}$	$S°/_{oo}$	σ_t
I.	54°N.; 3°30′W.	1.40 p.m.	15·2	18·42	33·28	24·83
II.	54°N.; 3°47′W.	3.0 p.m.	14·6	18·74	33·86	25·19
III.	54°N.; 4°4′W.	4.10 p.m.	14·0	18·98	34·29	25·66
IV.	54°N.; 4°20′W.	5.15 p.m.	14·0	18·98	34·29	25·66

Station V., 53° 53′ N.; 4° 46′ W. 30/7/12 (8.20 a.m.)

Depth (metres)	T°	$Cl°/_{oo}$	$S°/_{oo}$	σ_t
0	13·1	19·02	34·36	25·90
90	13·0	19·02	34·36	25·92

Station VI., 53° 43′ N., 4° 44′ W. 30/7/12 (9.30 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·37	19·04	34·40	25·88
30	13·2	—	—	—
54	13·15	19·05	34·42	25·93

Station VII., 53° 33′ N.; 4° 41′ W. 30/7/12 (10.45 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	14·0	19·03	34·38	25·73
30	13·8	—	—	—
84	13·8	19·03	34·38	25·77

Stations X to XXIV. Surface observations only. (Stations VIII and IX were omitted on this trip.)

Station.		Date and Time.		T°	Cl°/oo	S°/oo	σ_t
X.	53°37′N. ; 3°45′W.	30.7.12	p.m. 2.0	14·6	18·80	33·96	25·28
XI.	53°43′N. ; 3°58′W.	30.7.12	3.0	14·1	18·95	34·23	25·59
XII.	53°48′N. ; 4°12′W.	30.7.12	4.0	13·8	19·02	34·36	25·75
XIII.	53°54′N. ; 4°27′W.	30.7.12	5.0	13·4	19·01	34·34	25·82
XIV.	54°32′N. ; 4°37′W.	31.7.12	a.m. 9.50	14·8	18·72	33·82	25·13
XV.	54°37′N. ; 4°45′W.	31.7.12	10.40	14·8	18·56	33·53	24·90
XVI.	54°35′N. ; 4°27′W.	31.7.12	11.40	14·9	18·66	33·71	25·02
XVII.	54°34′N. ; 4°12′W.	31.7.12	p.m. 12.40	14·8	18·62	33·64	24·99
XVIII.	54°32′N. ; 3°55′W.	31.7.12	1.35	14·9	18·61	33·62	24·95
XIX.	54°29′N. ; 3°43′W.	31.7.12	1.53	15·2	18·55	33·51	24·81
XX.	54°24′N. ; 3°57′W.	31.7.12	5.0	14·7	18·64	33·68	25·04
XXI.	54°20′N. ; 4°13′W.	31.7.12	5.50	14·5	18·80	33·96	25·30
XXII.	54°15′N. ; 3°57′W.	31.7.12	6.50	14·9	18·67	33·73	25·03
XXIII.	54°10′N. ; 3°42′W.	31.7.12	7.50	14·7	18·55	33·51	24·91
XXIV.	54°5′N. ; 3°27′W.	31.7.12	8.50	15·4	18·28	33·03	24·41

September 10-11, 1912.

Stations I to IV., 10/9/12. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N.; 3°30′W.	2.45 p.m.	13·4	18·34	33·13	24·89
II.	54°N.; 3°47′W.	4.30 p.m.	13·6	18·43	33·30	24·97
III.	54°N.; 4°4′W.	5.30 p.m.	13·6	18·76	33·89	25·43
IV.	54°N.; 4°20′W.	6.30 p.m.	13·4	18·86	34·07	25·62

Station V., 53° 53′ N.; 4° 46′ W. 11/9/12 (8.20 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·25	19·00	34·33	25·84
30	13·0	19·00	34·33	25·89
75	13·25	19·00	34·33	25·84

Station VI., 53° 43′ N.; 4° 44′ W. 11/9/12 (9.30 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·5	19·05	34·42	25·85
30	13·1	19·04	34·40	25·92
73	13·4	19·04	34·40	25·86

Station VII., 53° 33′ N.; 4° 41′ W. 11/9/12 (10.40 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·9	19·04	34·40	25·76
30	13·6	19·03	34·38	25·81
56	13·65	19·03	34·38	25·80

October 7-8, 1912.

Stations I to IV., 7/10/12. Surface observations only.

Station.		Time.	T°	Cl°/₀₀	S°/₀₀	σ_t
I.	54°N.; 3°30′W.	12.40 p.m.	12·0	18·29	33·04	25·09
II.	54°N.; 3°47′W.	1.40 p.m.	12·3	18·60	33·60	25·47
III.	54°N.; 4°4′W.	3.25 p.m.	12·9	18·87	34·09	25·73
IV.	54°N.; 4°20′W.	4.35 p.m.	12·2	18·94	34·22	25·96

Station V., 53° 53′ N.; 4° 46′ W. 8/10/12 (8.25 a.m.)

Depth (metres)	T°	Cl°/₀₀	S°/₀₀	σ_t
0	12·4	19·03	34·38	26·05
30	12·3	19·02	34·36	26·05
90	12·35	19·01	34·34	26·03

Station VI., 53° 43′ N.; 4° 44′ W. 8/10/12 (9.35 a.m.)

Depth (metres)	T°	Cl°/₀₀	S°/₀₀	σ_t
0	12·83	19·05	34·42	26·00
30	12·7	19·05	34·42	26·02
66	12·8	19·05	34·42	26·00

Station VII., 53° 33′ N.; 4° 41′ W. 8/10/12 (10.45 a.m.)

Depth (metres)	T°	Cl°/₀₀	S°/₀₀	σ_t
0	13·25	19·08	34·47	26·15
30	13·05	19·06	34·43	26·17
57	13·2	19·06	34·43	26·13

November 4-8, 1912.

Stations I to IV., 4/11/12. Surface observations only.

Station.		Time.	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
I.	54°N. ; 3°30′W.	1.0 p.m.	10·6	18·24	32·95	25·28
II.	54°N. ; 3°47′W.	2.0 p.m.	10·5	18·45	33·33	25·58
III.	54°N. ; 4°4′W.	3.0 p.m.	11·1	18·81	33·98	25·99
IV.	54°N. ; 4°20′W.	4.0 p.m.	11·2	18·92	34·18	26·12

Station V., 53° 53′ N, ; 4° 46′ W. 5/11/12 (10.5 a.m.)

Depth (metres)	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
0	11·8	18·99	34·31	26·11
30	11·9	18·99	34·31	26·09
88	11·8	19·03	34·38	26·17

Station VI., 53° 43′ N. ; 4° 44′ W. 5/11/12 (11.15 a.m.)

Depth (metres)	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
0	12·2	19·06	34·43	26·14
30	12·0	19·05	34·42	26·15
44	12·1	19·06	34·43	26·15

Station VII., 53° 33′ N. ; 4° 41′ W. 5/11/12 (12.20) p.m.

Depth (metres)	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
0	11·9	18·92	34·18	26·00
30	11·85	18·92	34·18	26·01
56	11·85	18·91	34·16	25·99

Stations VIII to XXIV. Surface observations only.

Station.		Date and Time.		T°	Cl°/₀₀	S°/₀₀	σ_t
VIII.	53°27′N. ; 4°5′W.	6.11.12	a.m. 11.5	11·7	18·91	34·16	26·01
IX.	53°31′N. ; 3°31′W.	6.11.12	p.m. 1.20	10·4	18·25	32·97	25·32
X.	53°37′N. ; 3°45′W.	6.11.12	2.20	11·2	18·72	33·82	25·85
XI.	53°43′N. ; 3°58′W.	6.11.12	3.20	11·4	18·94	34·22	26·11
XII.	53°48′N. ; 4°12′W.	6.11.12	4.15	11·7	19·02	34·36	26·17
XIII.	53°54′N. ; 4°27′W.	6.11.12	5.10	11·4	19·00	34·33	26·19
XIV.	54°32′N. ; 4°37′W.	7.11.12	a.m. 9.10	11·6	18·97	34·27	26·14
XV.	54°37′N. ; 4°45′W.	7.11.12	10.0	11·2	18·86	34·07	26·04
XVI.	54°35′N. ; 4°27′W.	7.11.12	11.0	10·8	18·64	33·68	25·80
XVII.	54°34′N. ; 4°12′W.	7.11.12	12 n'n	10·8	18·73	33·84	25·93
XVIII.	54°32′N. ; 3°55′W.	7.11.12	p.m. 1.0	10·8	18·66	33·71	25·83
XIX.	54°29′N. ; 3°43′W.	7.11.12	2.0	10·2	18·28	33·03	25·40
XX.	54°24′N. ; 3°57′W.	7.11.12	3.5	10·5	18·44	33·31	25·57
XXI.	54°20′N. : 4°13′W.	7.11.12	4.10	10·8	18·82	34·00	26·05
XXII.	54°15′N. : 3°57′W.	8.11.12	a.m. 6.30	11·0	18·84	34·04	26·05
XXIII.	54°10′N. ; 3°42′W.	8.11.12	7.30	11·0	18·65	33·69	25·78
XXIV.	54°5′N. ; 3°27′W.	8.11.12	8.25	10·2	18·26	32·99	25·37

December 3-4, 1912.

Stations I to IV., 3/12/12. Surface observations only.

Station.		Time.	T°	Cl°/₀₀	S°/₀₀	σ_t
I.	54°N. ; 3°30′W.	8.20 a.m.	7·4	18·08	32·66	25·54
II.	54°N. ; 3°47′W.	9.20 a.m.	8·3	18·46	33·35	25·96
III.	54°N. ; 4°4′W.	11.15 a.m.	8·6	18·63	33·66	26·15
IV.	54°N. ; 4°20′W.	12.30 p.m.	9·1	18·91	34·16	26·46

Station V., 53° 53′ N. ; 4° 46′ W. 4/12/12 (8.45 a.m.)

Depth (metres)	T°	Cl°/₀₀	S°/₀₀	σ_t
0	10·2	18·96	34·25	26·35
30	10·2	18·95	34·23	26·34
60	10·1	18·95	34·23	26·36

Station VI., 53° 43′ N. ; 4° 44′ W. 4/12/12 (9.55 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·1	18·98	34·29	26·40
30	10·1	18·97	34·27	26·39
50	10·1	18·97	34·27	26·39

Station VII., 53° 33′ N. ; 4° 41′ W. 4/12/12 (11.5 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·5	19·04	34·40	26·42
30	10·4	19·04	34·40	26·44
90	10·35	19·04	34·40	26·44

THE PLANKTON ON THE WEST COAST OF SCOTLAND IN RELATION TO THAT OF THE IRISH SEA.—PART III.*

BY W. A. HERDMAN, F.R.S., AND WM. RIDDELL, M.A.

In continuation of our attempt to trace the planktonic conditions in the sea lying to the West of Scotland and North of Ireland in relation to those in the Irish Sea, a series of further observations were taken from the S.Y. "Runa" during August, 1912. It will be remembered that in several previous summers we obtained at certain localities considerable hauls of phyto-plankton such as are not to be found in the Irish Sea at that time of year, and the suggestion was made that the vernal phyto-plankton, which ceases in our more southern seas some time about May, persists to a later period in the more northern waters—especially in the more land-locked fjords and between the islands, where possibly it is not brought into competition with invasions of oceanic organisms.

A further point of interest which seemed to call for investigation was the distribution of the oceanic plankton, and its connection with the physical conditions in a wide sense. During the first few summers (1907-10) we had worked among the inner islands and sea-lochs, from the Clyde Sea-Area to Skye; while last year (1911) we extended the observations as far North as was possible in the time—to Lerwick in the Shetlands. This year (1912) our object was to work still further to the West, along the line of the Outer Hebrides, and to sample the open Atlantic water to the South of Barra

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* Parts I and II were printed in the Fisheries Laboratory Reports for 1910 and 1911.

Head. We had hoped possibly to get observations from as far out as St. Kilda, but that was found to be impracticable in the series of gales we encountered during that exceptionally unsettled summer.

The same types of nets and instruments were used as on the previous cruises—the Nansen net (with No. 20 silk) used on the Lucas Sounding Machine for vertical hauls, various open tow-nets for horizontal surface work, and the large shear-net for occasional hauls in the intermediate waters; the salinity readings were taken with Kiel aräometers, since tested by titration and corrected, and the temperatures with the standardised Kiel thermometers. The physical observations on this cruise were all taken by George Herdman, and a list of these in detail will be found at the end of this paper.

The itinerary was as follows:—We left Port Erin in the Isle of Man at 11-0 p.m. on July 30th, and reached Lowlandman's Bay, in Jura, on the evening of July 31st, and Oban on August 1st. For the next two days we were taking observations in the Firth of Lorn round Kerrera and Lismore islands, and reached Tobermory Bay, in Mull, on the night of August 3rd. On the morning of the 5th we took some vertical hauls in the deep water at the north end of the Sound of Mull, and then crossed the Sea-of-the-Hebrides by Hyskeir, in bad weather, to Castle Bay, Barra. For the next two days we worked round the south end of the Outer Hebrides, trawling and taking tow-net samples and physical observations; and then, on the morning of August 8th, started northwards through the Sea-of-the-Hebrides past Barra, Eriskay, the Uists, and the Long Island, taking three days to reach Stornoway, in Lewis. During this traverse, besides taking plankton hauls in the open sea, we entered some of the lochs on the eastern side of the islands and sampled these less open western waters. After a day at Stornoway, we crossed the Minch on August 12th, by the East Shiant Bank, to Loch Ewe in Ross-shire, where we were detained for a day by a heavy gale. On the 14th we commenced to work southwards inside Skye, taking observations in Gair Loch, Loch Torridon, Sound of Raasay, Loch-na-Beiste, the Narrows of Skye, Loch Alsh, Sound of Sleat and Loch Nevis, which occupied the time until August 19th. On that day we ran from Loch Nevis, by Eigg and Muick Islands and round the west of Mull, to the Sound of Iona where we remained over the 20th, and put in that evening to Ulva Channel in Loch-na-Keal, after a visit to Inchkenneth. A gale on the 21st kept us still sheltering behind the island of Ulva, and on the morning of the 22nd we worked round Gometra and the Treshnish group, and along the north coast of Mull. On the 23rd we took observations round Ardnamurchan and to the south of Muick, and reached Tobermory Bay that night. On the 24th we worked down the Sound of Mull to Oban, and remained over the 25th in Dunstaffnage Bay, at the entrance to Loch Etive. During the 26th we made a traverse south along the Firth of Lorn to the Isles of the Sea, and up north again to Oban Bay. On the 27th we started southwards for home, taking observations in Kerrera Sound, off the Isles of the Sea, off Colonsay and Oronsay, and through the Sound of Islay to Lowlandman's Bay in Jura. The following day we crossed the sound of Jura to Loch Swen, and worked up to Tayvallich. On the 29th we started from Loch Swen, in bad weather, down the Sound of Jura, and ran for shelter at night behind Gigha. On the 30th, still pursued by the gale, we came round the Mull of Cantyre, and got into Larne Lough in the North of Ireland at night. The following day, leaving Larne at 7-0 a.m., we took a series of hourly observations across the northern part of the Irish Sea, and arrived in Port Erin Bay at 2-0 p.m. on August 31st—having traversed about eleven hundred and twenty sea-miles.*

We had taken in all, on the 32 days of the cruise, 90 temperature observations and 89 readings of the aräometer, and 43 hauls of the tow-nets, besides those of the dredges and trawls which are not under consideration in this paper.† The temperatures ranged during the month from 11·36° C. to 13·52° C., while in the unusually warm summer of 1911 the range in much the same waters was from 11·2° C. to 17·8° C. The greatest salinity record in 1912 was 27·2 (= 34·6 $^\circ/_{\circ\circ}$, corrected), "off the island of Eriskay, two miles east of Binch buoy, Sound of Barra open," and "four to eight miles east of Ushinish lighthouse," on the east coast of South Uist, both on August 8th; and also in the Minch between East Shiant Bank and Ru Rea on August 12th; and four records of 27·1 occur on the eastern side of the Outer Hebrides; while in the Shetland cruise of 1911 we got readings up to 27·6 in the open sea to the east of the Shetlands on August 12th, and several of 27·2 to 27·4 between the Orkneys and the Shetland Isles, but nothing higher than 27 in Hebridean or Scottish waters.

(For further particulars of the physical observations see the list on p. 370).

Of the sixteen deep, vertical hauls with the Nansen net, seven were from 100 fathoms or over, the two deepest being 145 fathoms on August 7th, "Barra Head light-

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* A glance at the Chart reproduced as fig. 1 on p. 369 will give some idea of the distribution of land and water in this most diversified region. Notice especially the great extent of the chain of the Outer Hebrides.

† For some of the results of the bottom work see "Spolia Runiana," Journ. Linnean Soc., Zool., 1913.

house W. by N., Hesker Island N.W., outer edge of Muldoanich N.E. by N.½N"; and 113 fathoms on August 2nd, N.W. of Bhaic Island, in the Firth of Lorn.

As our main object in this paper is to discuss the nature of the plankton, we shall now consider the various tow-net hauls in some detail. The list is as follows:—

"Runa," 1912—Plankton Hauls.

The following are used in the right-hand columns:—

Z = Zoo-plankton, P = Phyto-plankton.
N = Neritic, O = Oceanic.
Z + p = A small amount of phyto-plankton with the zoo-pl.
O + n = A few Neritic forms with an Oceanic gathering.

Date.		Locality.	Depth.	Quantity.	Nature.	Former years.
Aug.	2	N.W. of Bhaic Island	113 faths.	Small	Z+p, O+n	P.N (Z.1911)
,,	5	Off Ardmore, N. of Mull ...	109 faths.	Medium	Z, O	P.N (Z.1911)
,,	6	Castle Bay, Barra..............	Surface	Sm.	Z+p, N+o	Same
		*5 miles E. of Muldoanich ...	107 faths.	Med. +	Z+p, O	—
		*5 miles E. of Muldoanich ...	Surface	Sm.	Z+P, O	—
,,	7	*Off Barra Head, Bernera ...	Surface	Sm.	Z+p, O+n	—
		*Off Barra Head, Bernera ...	145 faths.	Med.	Z, O	—
,,	8	*Off Eriskay	102 faths.	Med.	Z, O	—
,,	9	*4 miles E. of Loch Eport ...	94 faths.	Med.	Z, O	—
,,	10	*Upper Loch Seaforth	Surface	Med.	P, N	—
		*Mouth of Loch Seaforth......	42 faths.	Med.	P, N	—
		*Mouth of Loch Seaforth......	Surface	Med.	P, N	—
,,	12	*East Shiant Bank	Surface	Sm.	Z, O	—
		*Off Ewe Island	Surface	Large	Z+p, O+N	—
,,	15	Outer Loch Torridon	50 faths.	Sm.	Z+p, O	Same
		Outer Loch Torridon	Surface	Sm.	Z+p, O	Same
		*Loch Shieldag	35 faths.	Sm.	Z+p, O	—
		*Loch Shieldag, nearer Kyle..	70 faths.	Med.	Z+p, O	—
		Upper Loch Torridon	Surface	Med.	P+z, O+N	Same

Date.		Locality.	Depth.	Quantity.	Nature.	Former years.
Aug.	17	Middle Loch Nevis	79 faths.	Med.	Z, O	Same
		Middle Loch Nevis	Surface	Sm.	Z, O	Same
,,	18	Tarbet, Loch Nevis (night)...	Surface	Sm.	Z, O	Same
,,	19	*Off Muick Island	105 faths.	Med.	Z, O	—
		Between Lunga and Staffa ...	70 faths.	Med.	Z+p, O	Same
		S. End of Staffa	Surface	Med.+	Z, O	Same
,,	22	*W. of Gometra	Surface	Sm.	Z, O	—
		*N. of Mull	Shear	La.	Z, O	—
		*N. of Mull	Surface	Med.+	Z, O	—
		Off Ardmore Point	78 faths.	Med.+	Z, O	Same, 1911
		Off Ardmore Point	100 faths.	Med.+	Z, O	Same, 1911
,,	23	*S.E. of Muick Island	Shear	La.	Z, O	—
		*S.E. of Muick Island	Surface	Med.+	Z, O	—
		S. of Ardnamurchan............	Shear	Vy.la.	Z, O	Same, 1911
		S. of Ardnamurchan............	Surface	La.	Z, O	Same, 1911
,,	24	*Off Ardtornish Point	Shear	Sm.	Z, N+o	—
		*Off Ardtornish Point	Surface	Med.	P, O+n	—
		*Off Ardtornish Point	72 faths.	Med.	P, N+o	—
,,	25	*Dunstaffnage Bay	Surface	Sm.	Z, O	—
,,	26	*Off Isles of Sea	Surface	Sm.	Z+p, O+n	—
,,	27	*Off Colonsay	Surface	La.	P+z, N+o	—
,,	28	*S. of Tayvallich	Shear	Med.	Z, O+n	—
		*N. of Tayvallich	Shear	Med.	Z, O+n	—
		*N. of Tayvallich	Surface	La.	P, N	—
		*Tayvallich Bay	Surface	La.	P, N	—

* Those marked with an asterisk are new localities not visited on our previous plankton cruises.

Some of these hauls were at localities visited in previous years at about the same time of year, and are thus comparable with the former ones. The rest are from new localities not reached in the previous cruises. We have grouped them as far as possible in natural districts, some at least of which correspond with those discussed in the former reports.

Firth of Lorn.

August 2nd, N.W. of Bhaic Island, 113 fathoms. This is practically the same spot as "between Kerrera and Mull," July 21st, 1909, 80 fathoms, and July 24th, 1911, 110 fathoms. The present gathering agrees with that of 1911 in being mainly a fine zoo-plankton. There is, however, a small mixture of phyto-plankton, formed by some neritic Diatoms, notably *Eucampia zodiacus*, *Lauderia borealis* and a couple of species of *Rhizosolenia*. In 1909 the gathering, though still a mixture, was rather more phyto-planktonic than on the other two more recent occasions. On each occasion again there has been some admixture of oceanic and neritic types. In 1909 the neritic predominated, and on the present occasion the majority of the species are oceanic in the proportion of about two to one.

Although the Firth of Lorn is open to the Atlantic to the south of Mull, the plankton does not seem to be so thoroughly oceanic in its nature as that which comes in north of that great island in the region round Ardnamurchan. Possibly the North Atlantic drift sweeps northwards from outside Islay towards the Outer Hebrides without approaching the inner islands and channels until it reaches the Sea-of-the-Hebrides between Barra Head and Tiree, and then sends a branch inwards towards the north of Mull. Such a distribution might account for some of this year's observations.

A surface gathering on August 25th in Dunstaffnage Bay, off the Firth of Lorn, North of Oban, shows an oceanic zoo-plankton with very few Diatoms and a few neritic animals. Most of our hauls about this neighbourhood* in former years had more phyto- than

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* Not, however, at quite the same locality, but further south off Kerrera, Bernera and Lismore in the Firth of Lorn.

zoo-plankton, and the Diatoms present were chiefly neritic forms. But these former hauls in 1909 and 1910 were fully a month earlier, about July 21st; so it is possible that on the present occasion the neritic Diatoms had disappeared and been replaced by Copepoda and a few other animals. In 1911, however, the hauls in the Firth of Lorn on July 24th to 26th were zoo-planktonic in character.

Dunstaffnage Bay is close to the entrance of Loch Etive, where, in 1896, the late Mr. George Murray found the neritic diatom *Skeletonema costatum* in great abundance in August—in marked contrast to the mainly oceanic zoo-plankton that prevailed in that neighbourhood this year. We cannot, however, say that the plankton in Dunstaffnage Bay is necessarily any guide to what was present at the same time in Loch Etive, so much may these fjord-like inlets on the West Coast of Scotland differ from one another in their characteristic organisms.

We have two surface hauls taken further south in the Firth of Lorn, or the open water outside;—on August 26th off the Isles of the Sea, and on August 27th off the island of Colonsay. Both show an admixture of zoo- and phyto-plankton, and of oceanic with neritic forms; and, contrary to what one might have expected, the gathering which was taken further out in the open sea off Colonsay is the more neritic of the two, and also contains by far the larger numbers of Diatoms, at least ten species being well represented, and most of them, moreover, were neritic. So that the Colonsay gathering might well be described as a phyto-plankton with an admixture of some animals, and also as being neritic in character with a few oceanic forms added, chiefly Copepoda.

It must be remembered that even if some oceanic plankton is carried up this channel, the proximity of numerous small islands and rocks, and of the long coast lines of Mull, Islay and Jura, is bound to supply some neritic forms, and these may be carried unusually far out to sea by the strong tidal currents that prevail here in the neighbourhood of the Coryvrechan whirlpool.

NORTH END OF MULL.

This year we have had three vertical hauls from practically the same spot, off Ardmore at the north end of the Sound of Mull, one on August 5th from 109 fathoms, and two on August 22nd from 78 and 100 fathoms. All three were of very much the same type, in each case mainly zoo-plankton added to a certain amount of phyto-plankton, from four to six species of Diatoms, represented by numbers of some hundred to about forty thousand individuals each, and the general nature of the majority of the species in each case is oceanic. All this agrees very closely with the haul taken on July 11th, 1911, from 105 fathoms, but differs markedly from the phyto-planktonic and mainly neritic hauls obtained at that same spot in July, 1909 and 1910. The evidence seems to point to the conclusion that earlier in the season the water in that region may be occupied by a neritic phyto-plankton, which becomes replaced later on by an invasion of zoo-plankton from outside. If that explanation is correct, then it would appear that the phyto-plankton lingered on to a later date in 1909 and 1910, or that the oceanic invasion was greater in 1911 and 1912. As distinctly oceanic forms which made their appearance in the Ardmore vertical hauls this year we may note the Copepod *Metridia lucens* (in every haul) and the Siphonophore *Cupulita sarsi* (see below).

Three surface hauls taken this year rather further out, off "The Cailliach" at the N.W. corner of Mull and between the north of Mull and Ardnamurchan, showed an oceanic zoo-plankton. Shear-net hauls obtained on the same days (August 22nd and 23rd) off the north coast of Mull, off Ardnamurchan and to the S.E. of the Island of Muick, also showed an oceanic zoo-plankton containing many specimens of the pelagic Tunicate, *Doliolum tritonis*, a notably North Atlantic organism. The vertical haul taken on August 19th this year off Muick Island was likewise of the same nature, almost wholly zoo-planktonic of an oceanic type, and containing some specimens of *Doliolum tritonis*.

A small surface gathering taken on August 23rd to the S.E. of Muick was composed wholly of oceanic organisms, with the exception of a few individuals of the Cladoceran, *Evadne nordmanni*.

We have had no gatherings in previous cruises in quite this same region off Ardnamurchan and between the north of Mull and the southernmost of the small isles, with which the above hauls can be compared. Further north, however, round Eigg and Canna, some phyto-planktonic samples were obtained in 1910. This year, at any rate, the Atlantic water carried oceanic organisms as far in as the channel between Mull and Ardnamurchan.

OUTER HEBRIDES.

Most of the localities in this region were new ground untouched in our former cruises.

A vertical haul on August 7th, S.E. of Barra Head Lighthouse on the Island of Bernera, the southernmost of the Outer Hebrides, is the deepest (145 fathoms) in the whole series, and is also the one that was taken through water that is most nearly the open Atlantic. The catch is, as would naturally be expected, an oceanic zoo-plankton. Comparatively few Diatoms are represented, and only one of these, *Rhizosolenia shrubsolei*, is regarded as neritic. The only neritic animals, apart from a few larvae, are the universally present ("panthalassic") Tintinnidae. Amongst characteristically oceanic organisms we have *Euchaeta norvegica* and *Cupulita sarsi*. We add the full list as a record of our deepest haul.

S.E. of Barra Head, Bernera. August 7th, 1912. 145 fathoms.

Calanus finmarchicus	3,000
Pseudocalanus elongatus	1,300
Euchaeta norvegica	1
Acartia clausi	150
Oithona similis	2,000
Nauplii	10,000
Decapod larvae	2
Sagitta bipunctata	25
Plutei	450
Cupulita sarsi	1
Medusoids	15
Tintinnidae	800
Peridinium spp.	1,700
Ceratium fusus	150
Biddulphia regia	150
Corethron criophilum	150
Coscinodiscus radiatus	450
Rhizosolenia semispina	41,600
,, shrubsolei	92,500

The nearest approach to this locality in our former series of observations was the haul taken on July 14th, 1911, from 80 fathoms, at ten miles south of Castle Bay, Barra, and that gave, as on the present occasion, a coarse oceanic zoo-plankton.

We have also in the present year a surface gathering taken off Barra Head, Bernera, on the same occasion (August 7th), which gave, however, only a small haul in which both zoo- and phyto-plankton, both oceanic and neritic forms, are represented.

A pair of hauls, one vertical and the other surface, from some ten miles further north, off the Island of Muldoanich, on August 6th, gave much the same evidence. The vertical haul, from 107 fathoms, is mainly oceanic zoo-plankton, although Tintinnidae and the neritic Diatom, *Rhizosolenia shrubsolei*, are represented. The haul contains, however, the characteristic oceanic forms, *Metridia lucens* and *Cupulita sarsi*, and abundance of *Calanus finmarchicus*.

The surface gathering on the same day, five miles east of Muldoanich, does not show either *Metridia lucens* or *Cupulita sarsi*, and has very few *Calanus finmarchicus*. Like the corresponding haul the following day, off Bernera, it represents both phyto- and zoo-plankton, mainly oceanic in type. We may expect that even in water that is oceanic, when it approaches a coast there will, no doubt, be a certain admixture of neritic organisms derived from the animals and plants of the shore.

August 6th, Castle Bay, Barra. This gathering agrees fairly well with that taken on July 12th, 1910, in Vatersay Sound, which is simply the channel through to the Atlantic at the mouth of Castle Bay. In each case there is a mixture of zoo- and phyto-plankton and of oceanic and neritic types. In the present year the neritic diatoms were perhaps rather more in evidence than on the former occasion. The difference in date, nearly a month later this year, must be borne in mind.

Continuing up the line of the Outer Hebrides, in waters that had not been examined on any of our previous cruises, we had a vertical haul on August 8th, from 102 fathoms, two miles off the Binch Buoy to the east of the Island of Eriskay. This gathering was mainly zoo-plankton, and was certainly oceanic in type.

Like some of the previous hauls, it contained *Cupulita sarsi* and a large number of *Calanus finmarchicus.* There was also one specimen of *Nyctiphanes couchii.* The aräometer record here was 27·2, and the pure Atlantic water no doubt comes in here from the west through the wide Sound of Barra.

The next vertical haul further north was on August 9th, from 94 fathoms, at a spot five miles east of the mouth of Loch Eport in North Uist, and this again showed an oceanic zoo-plankton containing a large number of *Calanus finmarchicus* and other oceanic Copepods, amongst which we found one hundred specimens of *Metridia lucens.* The neritic *Evadne nordmanni* also occurs in this gathering.

We have next two hauls, one vertical and the other surface, taken at the same time in the outer part of Loch Seaforth, between Harris and Lewis, on August 10th. The vertical haul was from 43 fathoms, and was a large gathering of a phyto-planktonic character, and mainly neritic. As it was the most abundant haul that we obtained in the Outer Hebrides, we insert the details here, as follows:—

Outer Loch Seaforth. August 10th, 1912. 42 fathoms.

Calanus finmarchicus	50
Pseudocalanus elongatus	39,000
Acartia clausi	570
Oithona similis	2,300
Metridia lucens	1
Nauplii	10,200
Plutei	1,150
Lamellibranch larvae	2,300
Medusoids	12
Pleurobrachia pileus	1
Tintinnidae	24,000
Oikopleura dioica	1,150
Peridinium spp.	3,000
Dinophysis acuta	570
Asterionella bleakleyi	570
„ japonica	570

Chaetoceras boreale	27,300
,, breve	1,603,000
,, constrictum	355,700
,, debile	60,000
,, decipiens	410,400
,, teres	86,600
,, spp.	4,286,400
Corethron criophilum	2,300
Coscinodiscus radiatus	1,150
Eucampia zodiacus	11,500
Guinardia flaccida	5,700
Lauderia borealis	627,000
Nitzschia seriata	96,000
Rhizosolenia semispina	148,500
,, shrubsolei	131,100
,, stolterfothii	20,000
Thalassiosira gravida	22,800
,, nordenskioldii	46,200

It will be noticed that the Copepoda are mostly oceanic (including *Metridia lucens*), whereas the Diatoms, amounting in some cases to millions and in others to hundreds of thousands, are almost wholly neritic.

The surface gathering was of the same type, in its main character a neritic phyto-plankton, but having a few Copepoda and other animals that are regarded as oceanic.

Another surface haul was taken on the same day in Upper Loch Seaforth, above the island, some miles further inland than the position of the two last hauls. It is a well-marked phyto-plankton of neritic type, containing large quantities of Diatoms (common species of *Lauderia*, *Chaetoceras* and *Rhizosolenia*). This haul is very much of the same nature as the surface haul in the outer part of the loch, but is, if anything, as might be expected, even more markedly neritic.

The last of these Outer Hebridean samples was a surface gathering taken on August 12th in the middle of the East Shiant Bank when re-crossing the Minch towards Ru Rea. It is again an oceanic zoo-plankton, with no further features worthy of notice.

LOCHS ON MAINLAND NORTH OF SKYE.

We have five gatherings from Loch Torridon, all taken on August 15th:—A vertical haul from 50 fathoms and a surface haul in the Outer Loch; two vertical hauls (35 and 70 fathoms) from the branch known as Loch Shieldag; and a surface gathering from Upper Loch Torridon, beyond the Narrows or "Kyle." The last of these is mainly a phyto-plankton, but not a very large or marked one. Its main Diatom constituent is the oceanic *Rhizosolenia semispina*, but it also contains the neritic *Rhizosolenia shrubsolei*. This gathering then is not so striking as the one taken on July 19th, 1911, in Upper Loch Torridon, when the Diatoms very markedly predominated, and we had over three hundred million individuals of *Nitzschia delicatissima* in each of two nets hauled simultaneously.

The other four hauls taken this year in the Torridon district were all of much the same character, oceanic zoo-plankton with a comparatively small amount of oceanic phyto-plankton. Practically the only neritic organisms present in all these hauls are some Tintinnidae. We print the details of the vertical haul from 70 fathoms in Loch Shieldag as a specimen.

L. Shieldag (Loch Torridon). August 15th, 1912. 35 fathoms.

Calanus finmarchicus	300
Pseudocalanus elongatus	3,450
Oithona similis	2,900
Metridia lucens	20
Nauplii	3,100
Thysanoessa raschii	4
Sagitta bipunctata	10
Tintinnidae	1,250
Peridinium spp.	7,800
Coscinodiscus radiatus	300
Nitzschia closterium	625
Rhizosolenia semispina	10,000

We have a surface gathering of much the same type as the above taken on August 12th from Loch Ewe, a little further north on the mainland. It is on the whole more neritic: the animals are much the same with the addition of the neritic *Evadne nordmanni* in numbers, and the Diatoms include the neritic *Guinardia flaccida* and *Lauderia borealis*.

SOUND OF SLEAT.

August 17th, middle of Loch Nevis, 76 fathoms. This is comparable with two vertical hauls from 70 fathoms on July 17th, 1908, one from 75 fathoms on July 14th, 1909, and also one from 70 fathoms on July 21st, 1911. In all these cases the gathering is mainly a zoo-plankton of oceanic type.

A surface haul on August 17th, 1912, contained no Diatoms, and the animals were mostly oceanic forms; and a night gathering in the little bay at Tarbet, Loch Nevis, where we were anchored on the 18th, showed also a small zoo-plankton only.

It is rather remarkable that this fjord, running far into the land and sheltered, though at some distance, from the open Atlantic by the peninsula of Sleat and the islands of Rum and Eigg, should so constantly show a zoo-plankton partly at least of oceanic type. The Sound of Sleat and the great lochs opening from it evidently must receive some oceanic plankton from outside to mix with the neritic forms they contain. It is possible that earlier in the summer they are filled with a neritic phyto-plankton, but we have never found them in that condition in July or August.

West of Mull.

Hauls taken in the open sea to the west of Mull always show zoo-plankton. We have three such gatherings this year in the neighbourhood of the Treshnish group—a vertical haul from 70 fathoms between Staffa and Lunga on August 19th; a surface gathering on the same date south of Staffa; and another surface gathering a little further north, on August 22nd, between the Tresnish Isles and Gometra. All consist chiefly of an oceanic zoo-plankton. We print the vertical haul as an example of such a gathering. None of the numbers are large. *Temora longicornis* and *Centropages hamatus* are neritic Copepoda, while all the rest are oceanic—*Candacia armata* and *Metridia lucens* are especially so, and are rarely found in the inshore waters. All the Diatoms are oceanic, with the exception of *Rhizosolenia shrubsolei.*

Between Staffa and Lunga (Treshnish Isles).	Aug. 19th, 1912. 70 fathoms
Calanus finmarchicus	700
Pseudocalanus elongatus	10,000
Acartia clausi	3,450
Oithona similis	625
Temora longicornis	300
Centropages hamatus	300
,, typicus	5
Candacia armata	1
Metridia lucens	10
Nauplii	23,400
Thysanoessa raschii	1
Decapod larvae	15
Sagitta bipunctata	36
Plutei	625
Gastropod larvae	1,875
Lamellibranch larvae	1,300
Tintinnidae	4,000
Oikopleura dioica	300
Medusoids	33
Peridinium divergens	1,300
Ceratium tripos	300
Chaetoceras densum	27,200
Coscinodiscus radiatus	300
Rhizosolenia semispina	3,450
,, shrubsolei	2,500

This region west of Mull is, of course, open to the Atlantic south of the island of Tiree (see chart, fig. 1, on p. 369), but whether oceanic plankton is carried in there, or through the wide channel north of Tiree and Coll towards Ardnamurchan and then down the north and west coasts of Mull we cannot say.

SOUND OF MULL.

Two hauls taken in the Sound of Mull between Ardtornish and the Avon Rock late in August (24th) show a well-marked phyto-plankton of mixed neritic and oceanic type. We print here the vertical haul, showing that it is mainly composed of neritic Diatoms with the addition of some oceanic animals.

Between Ardtornish and Avon Rock.	Aug. 24th, 1912. 72 fathoms.
Calanus finmarchicus	175
Pseudocalanus elongatus	5,600
Acartia clausi	1,250
Oithona similis	600
Nauplii	12,500
Thysanoessa raschii	1
Decapod larvae	2
Sagitta bipunctata	10
Medusoids	5
Pleurobrachia pileus	1
Tintinnidae	1,900
Peridinium spp.	5,000
Ceratium fusus	2,000
Chaetoceras boreale	5,000
„ debile	11,250
„ decipiens	8,100
„ schüttii	9,400
„ spp.	70,600
Eucampia zodiacus	14,400
Lauderia borealis	3,100
Rhizosolenia shrubsolei	3,750
„ stolterfothii	4,400

The surface gathering taken immediately after the vertical haul is distinctly a phyto-plankton, mainly composed of species of *Chaetoceras* and *Rhizosolenia.* It is probable, then, that *Calanus* and the other oceanic

Copepoda were in the deeper layers of water. These are more like the types of haul that we obtained in July, 1909 and 1910, at the northern end of the Sound of Mull, off Ardmore; but the present hauls are smaller in quantity. A haul of the shear-net taken in the same locality, off Ardtornish, near the southern end of the Sound of Mull, showed a small zoo-plankton. This is, of course, quite consistent with the two mainly phyto-planktonic hauls obtained at the same time with the much finer-meshed nets. It only means that the Diatoms passed through the large meshes of the shear-net, which therefore showed only the comparatively few larger animals (*Calanus*, and some other Copepoda, *Sagitta*, Medusoids and Decapod larvae) that were present with the phyto-plankton. The shear-net, moreover, corroborates the evidence of the vertical haul that the Copepoda were chiefly in the deeper water.

Sound of Jura.

Our last locality is at the upper end of Loch Swen, where we have two surface hauls in the neighbourhood of Tayvallich taken on August 28th. Both show well-marked phyto-plankton of neritic type, with in each case a few oceanic Copepoda added. Between the two, at least a dozen species of Diatoms are present in abundance.

Two hauls of the shear-net taken in Loch Swen on the same day, one to the south of Tayvallich and the other to the north, both show small hauls of zoo-plankton. The explanation is the same as we have given in the case of the shear-net haul in the Sound of Mull on August 24th. The fine phyto-plankton has all passed through the wide meshes of the shear-net, and only the coarser zoo-plankton which was present in relatively small quantity has been retained. Moreover, the shear-net was worked at a depth of about 10 fathoms, a zone where the larger Copepoda and Sagitta and various larvae are usually more abundant than they are at or near the surface where the finer nets were worked.

These surface hauls in Loch Swen, those in the Sound of Mull, those at the mouth of Loch Seaforth, and those in Upper Loch Torridon and off the south end of Colonsay, are the only ones in the whole series that can be described as a well-marked phyto-plankton. They are the only ones that are more or less comparable with the green, flocculent, diatomaceous gatherings which we obtained, in July, on some previous cruises on various parts of the West Coast, at localities where this year there was an oceanic zoo-plankton or more or less of a mixture.

Conclusions.

No less than three masses of sea-water of different origin and character may enter or affect the British seas in varying quantity, viz.:—(1) Arctic water such as normally surrounds Iceland, and may extend further southwards and eastwards towards the Faroes and Shetlands; (2) Atlantic water which impinges on the western shores of Ireland, and may flood the English Channel and extend round the Shetlands or down into the North Sea; and (3) coastal water such as occupies the Baltic, bathes the coasts of N.W. Europe generally, and to a large extent surrounds the British Islands.

The seas on the west coast of Scotland are on the border line of the last two kinds of water, and may be regarded as primarily an area of coastal water which is, however, periodically invaded to a greater or less extent by bodies of warmer and salter Atlantic water carrying in oceanic plankton. The variations which we find in different years in the nature and amount of the plankton, at the same localities, no doubt depend upon the volume and period of such invasions. They may depend also upon other factors, such as the weather (temperature, sunshine, rainfall, wind, &c.) at the time, and previously.

The phyto-plankton which was so wide-spread in July, 1909 and 1910, especially round Mull and the Small Isles, seems in the last couple of summers, and especially in August, 1912, to have become pushed back or restricted to the more land-locked waters by an unusual invasion of oceanic forms. Unfortunately, our observations this year were a month later than in 1907 to 1910, and it is impossible to say how much of the change which we have recorded must be ascribed to the natural decrease of phyto-plankton and increase of zoo-plankton as the season advanced. But even if some allowance be made for that, we think there can be no doubt from our hauls in the sea to the north of Mull that this summer there was an unusual influx* of characteristically Atlantic organisms, such as the Copepods *Metridia lucens* and *Candacia armata*, the Siphonophore *Cupulita sarsi*, and the pelagic Tunicate *Doliolum tritonis*.

Metridia lucens is an inhabitant of the oceanic waters of the North Atlantic which occasionally is carried in shoals into coastal areas such as the Irish Sea, Loch Fyne and the Minch. *Candacia armata* is also a North Atlantic form captured on various occasions off the south and south-west of Ireland, and has been recorded rarely from the Outer Hebrides, the Irish Sea and the Clyde Sea-Area. Both these Copepods indicate the presence of "Atlantic Drift" water.

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* Perhaps in the British Seas generally, as we have evidence of an unusual invasion of the English Channel and southern part of the Irish Sea by Atlantic Siphonophora in 1912. Numbers of *Physalia* and *Velella* were found cast up on the shores of South Wales and the South of England in March and April, and we have found *Muggiaea atlantica* in Cardigan and Carnarvon Bays in September.

Cupulita sarsi has occurred several times during recent years in the English Channel, and around the coasts of Ireland, but is still distinctly rare in British coastal waters, and may probably always be taken as an indication of an influx of Atlantic water.

Doliolum tritonis was first found* by Sir John Murray in 1883 during the cruise of the "Triton" in the Faröe Channel. On that occasion the specimens (which were so abundant that they masked the other contents of the tow-net, and between five and six thousand were brought back as a sample) were found to be drifting from the open Atlantic in the S.W. to the "Wyville-Thomson ridge" in the N.E. They were apparently plentiful during the greater part of the cruise, and so must have been present in that region of the North Atlantic in extraordinary profusion. Since the "Triton" expedition, this species has been found† by the Irish Fishery cruiser "Helga" and by the German Plankton Expedition on several occasions in the North Atlantic outside Ireland and in the Faröe Channel; but it has never, so far as we are aware, been recorded inside the Hebrides in such waters as we obtained it from this summer.

It is interesting to note that last year (1911), when none of the above-mentioned Atlantic forms were obtained, we found quantities of the oceanic pelagic Pteropod *Limacina retroversa* at many localities from the north of Mull to the Shetlands, while this year not a single Pteropod was seen.

Both 1911 and 1912 have been exceptional summers, and form a marked contrast in weather. August 1911 was unusually hot and dry, and the heat of the month

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* See Herdman, Trans. Roy. Soc., Edinburgh.

† See Farran, Fisheries Ireland Sci. Investgs., 1906, I.

has been recorded as "without precedent in the records of the country." On the other hand, August in 1912 was a cold, wet and stormy month, the mean temperature over the country as a whole being the lowest recorded in August for at least forty years.

At Douglas, Isle of Man, in the centre of the Irish Sea, where meteorological records have been kept for many years, we find that in 1911 the mean air temperature reached its maximum (60·8° F.) in August, while the total number of hours of bright sunshine (256), if not the actual maximum (279 hours was recorded in May), was still very high, and much higher than any month in 1912. The rainfall, moreover, was unusually low (1·93 inches) in August, 1911.

In 1912, on the other hand, the mean air temperature was only 53·6° F., and the total hours of sunshine 117, a figure exceeded by five other months in that year and by seven months in 1911, while the rainfall in August, 1912, was 5·17 inches, which is more than is shown for any other month that year, and nearly three times as much as that of August, 1911. The contrast between the two summers is seen clearly in this tabular statement:—

August	Temp.	Sun.	Rain.
1911	60·8	256	1·93
1912	53·6	117	5·17

We have before us also the statistics for Oban, which occupies a central position on the West of Scotland, and for Stornoway, which may be taken as representative of the Outer Hebrides, and find that they show the same contrast, except in the matter of rainfall, which seems to have been unusually heavy at Oban during August, 1911—although the hours of bright sunshine also give a high record for the same month, as the following table shows:—

August.	Temp.		Sun.		Rain.	
	Oban	S'way	Oban	S'way	Oban	S'way
1911 ...	60·8	57·4	199	166	4·61	3·92
1912 ...	54·0	51·2	70	99	3·81	5·59

If, then, temperature and the amount of sunshine during the month have any effect upon the amount and distribution of the plankton, here is a case where one would expect the effect to be well-marked.

The right columns of the list on p. 348 show that (after removing all those localities that were sampled for the first time in 1912) most of the remainder showed the same type of haul in 1912 that we recorded in 1911. A few, however, in the Firth of Lorn and on the north coast of Mull have lost their phyto-planktonic and neritic character, and must now be classed as oceanic zoo-plankton. But, on the other hand, the hauls taken off Colonsay, off Ardtornish in the Sound of Mull, and at the mouth of Loch Seaforth, along with some of the gatherings taken far up the lochs, such as those in Loch Swen, in Loch Seaforth and in Upper Loch Torridon, show phyto-plankton mainly of a neritic character. It is possible that the effect, if any, of the great heat and unusual amount of sunshine in August, 1911, was not shown by the plankton until later.

We showed last year* that in the Irish Sea a marked increase in the plankton in September and October, amounting to about nine times as much as in the same period of the previous year, seemed to correspond with the larger amount of sunshine in August, 1911 (194 hours recorded at Port Erin, as

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* Lancashire Sea Fisheries Report for 1911, p. 153.

against 80 hours in 1910). Unfortunately, there are no data available from the Hebridean waters later than August. There is a great want, as we have pointed out before, of a series of periodic observations on the West of Scotland, such as we now have year after year from Port Erin in the Irish Sea.

It seems unfortunate that the International Council for the Investigation of the Sea has not included the West Coast of Scotland in its scheme of work. It is the only part of our outer coastal waters that has not been systematically investigated. The West of Ireland and the North of Scotland are included in the periodic observations, and it is to be regretted that such an interesting connecting link as the Hebridean Seas should have been omitted from the official programme.

We see no reason to modify our view that the spring phyto-plankton seems to remain longer in northern Scottish waters than it does in the Irish Sea. It probably disappears more slowly some years than others, and it certainly seems to be replaced more on some occasions than on others by invasions of oceanic zoo-plankton. This summer there seems to have been a well-marked invasion of this character to the north of Mull, carrying even such an Atlantic organism as *Doliolum* almost into the Sound of Mull (see fig. 1).

It seems not unlikely that there is a definite connection between oceanic water containing *Calanus* in quantity and shoals of herrings in the Hebrides. We have noticed on several occasions that we obtained large hauls of *Calanus* at spots where either the night before or the night after good catches of herrings were reported. This is one of several matters upon which we hope on some future occasion to try to obtain more convincing evidence.

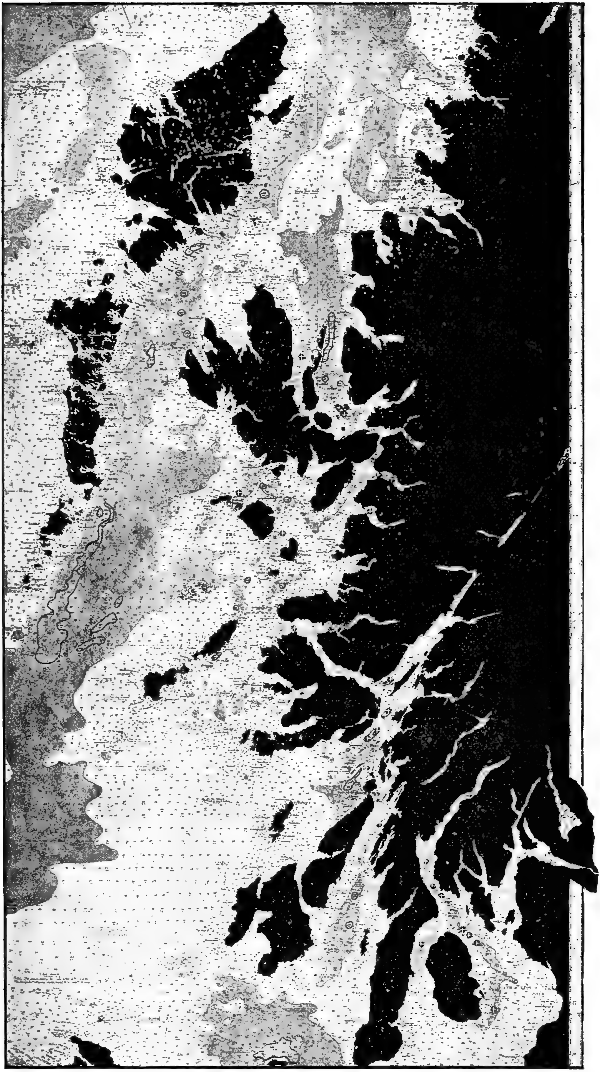

FIG. 1. Chart of West Coast of Scotland from Mull of Cantyre to Butt of Lewis.

"Runa," 1912. Physical Observations.

Date.		Time.	Locality.	Thermometer.	Aräometer.
July	31...	9.0 a.m.	2 miles N. of Maidens	11·88°C.	26·5
		10.0 a.m.	E. of Garron Point, 5 miles off	11·83	26·5
		11.10 a.m.	S. end of Rathlin Island bearing N.W.	11·81	26·6
		12.0 noon	Mull Lighthouse bearing E.N.E., 2 miles	11·97	26·5
		1.0 p.m.	Machrihanish bearing E.	12·30	26·6
		3.45 p.m.	Sound of Jura, off N. end of Gigha	12·41	26·6
Aug.	1...	8.0 a.m.	Lowlandman's Bay, Jura	11·90	26·4
		10.30 a.m.	Off Ruadh Rock (Sound of Jura)	11·97	26·3
		12.45 p.m.	Off Easdale Island	11·80	26·3
,,	2...	9.0 a.m.	Oban Bay	12·00	25·8
		10.45 a.m.	Between Oban and Lismore	12·07	25·5
		2.50 p.m.	Between Mull and Bhaic Island	12·00	25·7
,,	3...	8.0 p.m.	Sd. of Mull, betw. Salen and Tobermory.	12·10	26·0
,,	4...	9.30 a.m.	Tobermory Bay (high tide)	12·31	26·0
		2.15 p.m.	Tobermory Bay	12·44	25·7
		6.50 p.m.	Tobermory Bay	12·36	25·7
		9.30 p.m.	Tobermory Bay (after rain)	12·13	25·0
,,	5...	9.45 a.m.	Off Ardmore, Mull	12·40	26·0
		5.0 p.m.	Minch, between Hyskeir and Barra	12·46	26·1
,,	6...	9.30 a.m.	Castle Bay, Barra	12·40	26·9
		4.0 p.m.	5 miles E. of Muldoanich	13·20	26·9
,,	7...	11.15 a.m.	Pabbay bearing N.W.	12·52	27·1
		12.0 noon	4 miles S.E. of Barra Head, Bernera	12·92	27·1
,,	8...	11.0 a.m.	Off Eriskay, 2 miles E. of BinchBuoy	11·94	27·2
		2.30 p.m.	4 to 8 miles E. of Ushinish Lighthouse	12·21	27·2
,,	9...	10.0 a.m.	Off Ushinish Lighthouse	12·03	27·0
		4.30 p.m.	7 miles E.S.E. of Loch Maddy	11·86	27·1
,,	10...	11.30 a.m.	E. of Sound of Harris	12·26	27·0
		2.30 p.m.	Upper Loch Seaforth, above Island	12·36	26·7
		6.0 p.m.	Off Ru Hurnaway, S. of Stornoway	12·50	26·9
,,	11...	5.0 p.m.	At Stornoway {some fresh water	13·38	< 23
		9.0 p.m.	At Stornoway from river}	12·25	< 23
,,	12...	9.45 a.m.	1 mile S. of Stornoway	12·38	26·9
		10.30 a.m.	8 miles from Stornoway	11·74	26·9
		11.45 a.m.	On East Shiant Bank	12·38	27·1
		1.30 p.m.	Between E. Shiant Bank and Ru Rea	12·42	27·2
		2.45 p.m.	Off Ru Rea	12·62	27·0
		4.0 p.m.	Off Ewe Island	12·95	26·1
,,	14...	11.30 a.m.	S. of Ru Rea	11·54	26·9
		2.0 p.m.	Head of Gair Loch (much rain)	12·62	< 23
,,	15...	11.15 a.m.	Mouth of Gair Loch	12·0	26·9
		12.15 p.m.	Entrance of Loch Torridon	11·66	26·9
		1.30 p.m.	Loch Shieldag	11·36	26·9
		2.30 p.m.	Upper Loch Torridon	12·55	abt. 23·4
,,	16...	4.30 p.m.	Off Croulinbeg	12·46	26·8
		5.30 p.m.	Off Kyleakin	12·01	—
,,	17...	9.30 a.m.	Loch-na-Beiste	12·21	26·5
		10.45 a.m.	Loch Alsh	11·90	26·4
		2.30 p.m.	Sound of Sleat, below Glenelg	12·56	26·4
		?	Middle of Loch Nevis	12·19	26·5
,,	18...	2.15 p.m.	Tarbet, Loch Nevis	12·43	26·4
,,	19...	9.15 a.m.	Outer Loch Nevis	12·54	26·4
		12.15 p.m.	Off Muick Island	12·40	27·0
		1.45 p.m.	Off Cailliach Point, Mull	12·59	26·8
		8.30 p.m.	Sound of Iona	12·74	26·7
,,	20...	9.0 a.m.	In Iona Sound	12·60	26·7
		1.15 p.m.	In Iona Sound	12·60	26·6

Date.	Time.	Locality.	Thermometer.	Aräometer.
Aug. 21...	12.0 noon	In Ulva Channel	12·50	26·7
„ 22...	9.0 a.m.	Off W. of Gometra	12·33	26·9
	3.0 p.m.	Off N. of Mull	12·57	26·9
	5.0 p.m.	Off Ardmore Point	12·41	26·9
„ 23...	10.30 a.m.	Off Ardnamurchan	12·10	27·0
	12.30 p.m.	S. of Muick	12·15	27·0
	4.30 p.m.	Between Muick and Ardnamurchan	12·60	26·8
„ 24...	2.0 p.m.	Betw. Ardtornish Point and Avon Rock	12·8	26·0
„ 25...	3.0 p.m.	In Dunstaffnage Bay	13·02	abt. 23
„ 26...	9.0 a.m.	Off Dunstaffnage Point	12·41	25·3
	11.0 a.m.	Between Oban and Lismore Lighthouse	12·76	25·2
	2.30 p.m.	N. of Isles of the Sea	12·46	26·5
„ 27...	8.30 a.m.	S. end of Kerrera Sound....................	12·02	26·4
	9.30 a.m.	Between Sheep Island and Isles of the Sea	12·30	26·5
	10.30 a.m.	Between Isles of Sea and Colonsay......	12·40	26·5
	11.30 a.m.	Off E. of Colonsay	12·55	26·5
	4.30 p.m.	Between Colonsay and Sd. of Islay	12·75	26·6
	6.0 p.m.	E. end Sd. of Islay	12·20	26·6
	7.0 p.m.	Sd. of Jura, off Lowlandman's B.	12·20	26·7
„ 28...	9.0 a.m.	Off entrance Lowlandman's B.	12·25	26·6
	9.45 a.m.	Off Mor Island, Sd. of Jura	12·03	26·7
	11.0 a.m.	Loch Swen, off Tayvallich	12·90	26·3
	3.30 p.m.	Do. N. of Tayvallich	12·99	26·4
„ 29...	3.0 p.m.	Mouth of Loch Swen	12·24	26·6
	4.30 p.m.	Sound of Jura, N. of Gigha	12·43	26·7
„ 31...	7.30 a.m.	Entrance Larne Harbour	12·40	25·4
	8.30 a.m.	Off Belfast Lough	12·58	26·8
	9.30 a.m.	On Course (S. by E. ½ E.)	12·59	26·7
	10.30 a.m.	Do.	12·70	26·7
	11.30 a.m.	Do. (Bradda Hd., S.E. by S.) ...	12·78	26·8
	12·30 p.m.	Do. (Bradda Hd., S.E. by S., Contrary Hd., E. by S.) ...	13·19	26·8
	1.30 p.m.	Do.	13·52	26·7
	2.0 p.m.	Port Erin Bay	13·40	26·7

NOTE.—The Thermometer used has been checked against a standard instrument; the necessary correction is + 0·15°.

The Aräometer has been checked by titration, and the following correction must be applied:—Correct in the usual way for temperature (*K* in Knudsen's tables), then add 0·20 to the corrected reading to get $\rho_{17\cdot5}$.

For example, on August 7th, at noon, the corrected temperature would be 13·07 and the aräometer reading corrected for temperature becomes 26·23 and, with the final correction $\rho_{17\cdot5} = 26\cdot43$ and $S = 34\cdot60\ ^\circ/_{oo}$. The readings on the 8th when corrected give slightly lower results, but that on the 12th at 1.30 p.m. gives $S = 34\cdot61\,^\circ/_{oo}$, and this is the highest of the series.

AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.—PART VI.

By W. A. Herdman, F.R.S., Andrew Scott, A.L.S., and H. Mabel Lewis, B.A.

(With a plate and other illustrations.)

METHODS.

This work has been continued during 1912 on the same general plan as in preceding years. This completes the sixth year of this collection and detailed analysis of the plankton week by week, and we consider it desirable that, if possible, ten years of continuous observations should be accumulated before any change is made in the scheme of work. That, it is hoped, may enable us to draw conclusions which are not vitiated by the data of some exceptional year.

The work at sea in April, 1912, during the time of the vernal phytoplankton, was carried on from the steam-yacht "Runa," with the capable assistance of Mr. W. Riddell and his successor, Mr. H. G. Jackson; while in Port Erin Bay Mr. Chadwick and Mr. T. N. Cregeen, of the Biological Station, collected six samples a week throughout the year—two with a fine net (No. 20 silk), two with a coarse one (No. 9 silk), and two vertical hauls from 5 fathoms. The authors have divided the rest of the work between them on the same general lines as in previous years.

As in the case of the last report, we shall give here only a comparatively brief statement of results, selecting for discussion any points which seem new or which we have not dealt with before. Consequently, we must refer readers for fuller information in regard to the details of our methods and some of the results to the preceding five parts of this work (see Reports for 1907-1911).

MATERIAL AVAILABLE.

The collections made this year have amounted to nearly 400—all taken within the limited sea-area off the Isle of Man to which this "Intensive Study" is confined. The series of samples, including those of former years, is now as follows:—

Year.	At Sea, from Yacht.		In Bay throughout Year.	Totals.
	Spring.	Autumn.		
1907	218	279	138	635
1908	156	242	157	555
1909	329	147	231 + 49	756
1910	107	249	296	652
1911	120	84	314	518
1912	87	0	299	386
Totals ...	1,017	1,001	1,484	3,502

In addition to these plankton samples from the neighbourhood of Port Erin, the Fishery steamer "James Fletcher" has taken a large number of both vertical and horizontal plankton hauls in other parts of the Irish Sea during the past year, and other samples were taken from the "Runa" during the summer further North, along the West Coast of Scotland, all of which have been worked up in our laboratory and are available for comparison.

No change has been made during 1912 in the nets employed or the method of using them (see last Report, p. 128).

PLANKTON OF PORT ERIN BAY IN 1912.

As before, the plan of work is to take two horizontal hauls (coarse and fine nets) and one vertical haul on two occasions each week throughout the year—that is, six hauls per week, about 24 per month, and 312 in the year. The twelve months of 1912 are represented by their hauls as follows:—

Months ...	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
No. of Hauls	24	24	24	27	27	21	27	27	33	19	25	21

The work has thus been carried out for us with great regularity, and the average per month is about 25 hauls. The lowest monthly record is 19 for October, and the highest 33 for September. The high number in the latter month is due to some extra hauls having been taken in addition to the usual programme.

The upper whole-line curve in fig. 1 shows the total plankton caught in the horizontal tow-nets (coarse and fine added together) in Port Erin Bay during the months of 1912; while the lower broken line shows the corresponding curve for the hauls of the vertical net, multiplied by two for the sake of distinctness. Consequently, the scale on the left-hand margin applies only to the upper curve. The positions of the vernal and autumnal maxima are distinctly seen, and also the summer minimum in July and August.

Neglecting the vertical hauls at the mouth of the Bay, which give much the same result on a smaller scale as the horizontal nets (see fig. 1) but are not directly comparable with them, and treating the coarse and fine nets together as before, we get the following averages for the total plankton, and the number of individuals of the chief planktonic groups, per haul of the standard net for the twelve months:—

1912.	Double hauls.	Average catch.	Diatoms.	Dinoflagellates.	Copepoda.	Copepod juv.	Copepod nauplii.
January	8	2·7	48,409	4,697	6,227	0	4,605
February ...	8	2·8	60,409	1,611	3,346	0	5,940
March	8	15·4	4,099,737	19,235	2,801	400	23,967
April	9	25·5	21,267,907	2,233	3,213	0	13,204
May	9	36·3	27,891,917	1,299,576	53,742	4,456	191,089
June	7	37·5	46,824,314	24,014	74,129	0	122,643
July	9	13·6	40,966	2,684	32,620	389	39,789
August	9	13·1	683,874	306	31,996	271	32,196
September ...	9	23·4	8,172,122	2,681	46,207	0	27,904
October	7	9·6	242,486	679	75,577	0	35,463
November ...	8	3·2	41,642	5,409	14,078	0	6,470
December ...	7	6·4	11,659	1,423	6,044	0	1,803

This table may be compared with the similar ones in the last three Reports (Part III, p. 212, Part IV, p. 199 and Part V, p. 130). Compared with that for 1911, it shows a lower actual maximum in total catch (37·5 c.c. in June, 1912, as against 46 c.c. in May, 1911), but the general level of the catches from March to June is higher

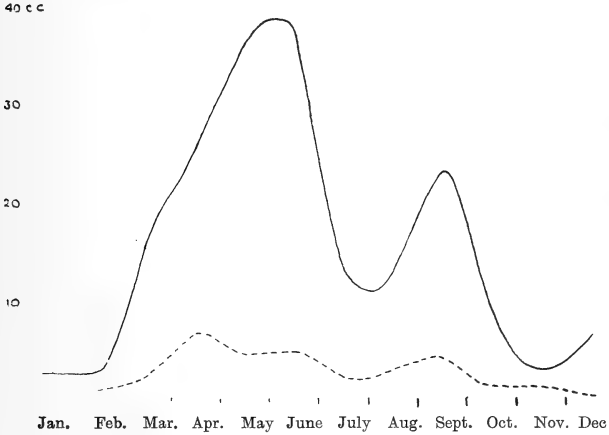

Fig. 1.—Total Plankton Curves (horizontal and vertical nets) in the Bay.

this year, and the vernal maximum seems to be spread over a great length of time. In 1912 the smaller but quite decided autumnal maximum is in September, and is greater than in 1911 (23·4 c.c. as against 15·3 c.c.). The Diatom maximum is a month later and nearly twice the bulk of that in 1911, but this is wholly due to the enormous quantities of *Rhizosolenia* taken in June; nearly 41 millions of the 47 millions in the table being due to *Rhizosolenia.* The well-marked Dinoflagellate maximum is in May (June in 1911), and is unusually high. The Copepoda reach their maximum at an unusually early date, at least a month before that of 1911, when the highest numbers were in July and August, while this year they are in May and June.

The table above and the remarks following it apply to the double hauls of the horizontal tow-nets; while the diagram below (fig. 2) represents the curves for total plankton, Diatoms, Dinoflagellates and Copepoda as captured in the vertical net at the mouth of the Bay. On the left-hand margin the volume in c.c. of the total plankton, and the separate scales for Diatoms, Dinoflagellates and Copepoda, respectively, are indicated.

The general correspondence with the results obtained from the much larger catches of the horizontal nets will be noticed.

DIATOMS.

Compared with the previous year, the appearance of Diatoms in quantities in the spring of 1912 was earlier. Nearly 2 millions was reached in the double haul as early as March 11th, and nearly 25 millions on March 21st, and these high numbers were sustained until the middle of June, the actual maximum being 202,993,600 on May 30th; whereas in 1911 millions were not reached until May 10th, and the numbers had dropped again by June 12th, and the maximum haul was only 69,982,500 on May 16th. So that, whereas last year we were able to show the rise and fall of the Diatom vernal maximum in a table (p. 133 in the last Report) giving the numbers throughout May and the first week of June, this year we should need to give them for the four months March to June in order to cover the period of the Diatom visitation.

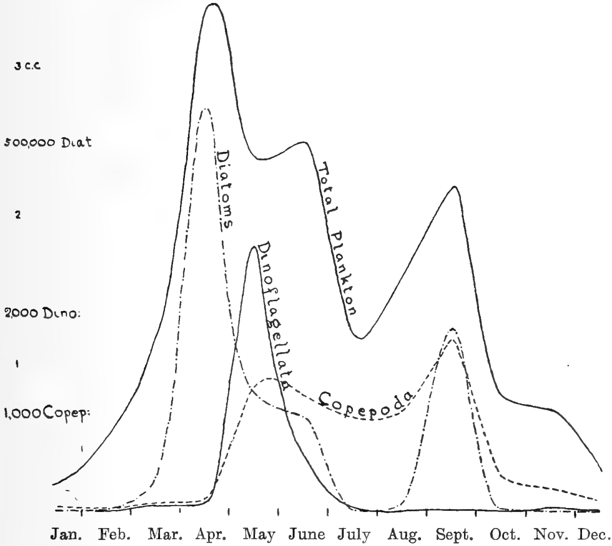

FIG. 2.—Curves for chief groups and total plankton of vertical net in Bay.

On analysing the vernal maximum into its constituent factors, it is found that species of *Chaetoceras* and *Rhizosolenia* are enormously more abundant than any other forms, and that the former is present in greatest quantity in March and April and the latter in

May and June. From the middle of May to the middle of June the bulk of the catch is composed of *Rhizosolenia*, but *Guinardia* is also represented by numbers of from 1½ millions to nearly 23 millions, and these two genera (along with a few tens of thousands of *Chaetoceras* and a few *Eucampia*) are the only Diatoms found in our nets in June.

The autumnal maximum was a few weeks earlier in 1912, and was higher; as in previous years, it consisted mainly of a few species of *Chaetoceras*.

THE MORE IMPORTANT GENERA OF DIATOMS.

We shall again pick out the more salient features in the distribution throughout the year of the same seven genera of Diatoms dealt with in previous reports.

Biddulphia.—This genus is represented, by a few thousands and tens of thousands only, from January to the middle of May, and again from the middle of September to the end of the year. The highest record is 88,240 on March 11th, and in autumn the highest is 69,960 on November 14th. These numbers are considerably lower than those for 1911. [See note (p. 380) on the species or "forms" of *Biddulphia* present.]

Chaetoceras.—The maximum this year is at the end of April with 94,733,000 on the 29th, 26 millions more than the maximum of 1911 (on May 16th). The autumnal maximum also is greater, with 29¾ millions on September 26th, as against 10½ millions on October 2nd, 1911.

Coscinodiscus.—The numbers are rather higher this year than in 1911, the highest record being 462,750 on March 21st, and the highest monthly average 100,619 for April. On May 9th there was a large haul of 119,600, but after that date the numbers dropped suddenly, and in June the genus was entirely absent. It appeared again in the middle of September, and rose to a second maximum of 35,000 on October 7th.

Rhizosolenia.—This genus was present in enormous quantities from the middle of May to the middle of June, and was much more abundant than we have ever known it before. The two highest records are 184 millions on May 30th and 173 millions on June 3rd—per standard haul in every case quoted. After dying down in the middle of July, *Rhizosolenia* was again present from September 13th for about a month, the highest haul being 647,000 on September 30th.

Thalassiosira.—There was one large haul of over 6 millions on April 29th, but the next highest was only 289,300. In 1911 the maximum was not until the end of May, by which time this year the genus had entirely disappeared. Its appearance in autumn was also earlier this year, but the numbers only reached 28,000 (September 30th), as against 287,000 on October 5th, 1911.

Guinardia.—This genus is unusually abundant this year, very high numbers being met with throughout May and June, and the maximum being 22,800,000 on June 3rd; 70,000 on September 30th is the highest record for the autumn.

Lauderia.—This form is more abundant than in 1911, but not so abundant as in 1910. The maximum is 12½ millions on April 29th, but only on that occasion did the numbers reach the millions.

We give here the monthly averages of these seven genera of Diatoms, as follows:—

1912.	Biddulphia.	Chaetoceras.	Coscinodiscus.	Rhizosolenia.	Thalassiosira.	Guinardia.	Lauderia.
Jan. ...	24,920	7,342	9,877	22	0	257	189
Feb. ...	36,885	10,301	10,034	12	0	105	0
Mar. ...	21,176	3,977,292	95,446	525	25	162	337
April ...	21,869	18,365,750	100,619	36,464	721,338	3,158	1,622,478
May ...	1,072	2,844,861	14,586	22,008,744	41,033	2,789,433	170,878
June ...	0	67,543	0	40,833,771	0	5,919,429	0
July ...	0	39,527	56	1,228	0	158	0
Aug. ...	11	694,961	0	13	0	0	0
Sept. ...	4,131	7,702,658	1,677	117,122	3,978	10,967	8,944
Oct. ...	5,827	214,421	11,914	820	57	2,176	29
Nov. ...	25,714	9,476	5,436	0	0	21	0
Dec. ...	8,059	1,106	1,573	0	0	141	0

The above table shows very clearly how the different genera reach their maxima at different times, and how *Chaetoceras* in spring gives place to *Rhizosolenia* and *Guinardia* in early summer.

NOTE ON THE FORMS OF BIDDULPHIA PRESENT.

Under the genus *Biddulphia* above we have, as in previous years, recognised and recorded two "species," *B. mobiliensis* and *B. sinensis* (see *a* and *b*, fig. 3), but some variations in these forms have been noticed of late upon which we wish to make some observations.

In the photo-micrograph (fig. 3), *a* points to what has been regarded hitherto as *B. mobiliensis* in our district, and *b* to a typical example of *B. sinensis*. Our *B. mobiliensis* undoubtedly approaches the form "regia," regarded as a distinct though allied species by Ostenfeld (Medd. Kom. Havunders., Plankton, Bd. I. 6, 1908). Gran, in the Diatomacea of the Nordisches Plankton, unites these two forms as *B. mobiliensis*, and we in recognition of the facts, as we conceive them, consider that they should be known respectively as *Biddulphia mobiliensis*, forma *regia*, Schultze, and *B. mobiliensis*, forma *sinensis*.

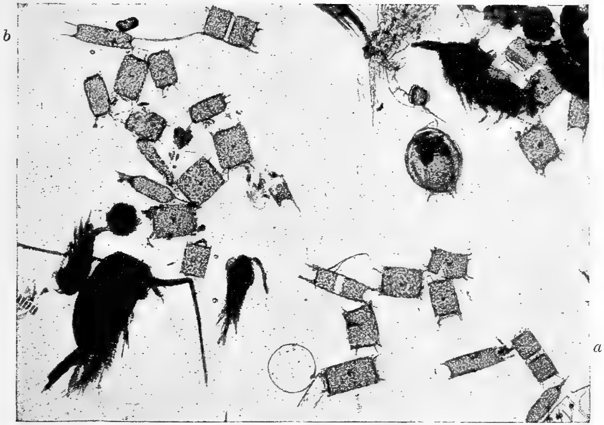

FIG. 3.—Photo-micrograph of a plankton haul showing (*a*) *Biddulphia mobiliensis*, forma *regia*; and (*b*) *B. mob.*, f. *sinensis*.

In the XVIIIth Annual Report (for 1909, p. 222) we recorded the discovery of *Biddulphia sinensis* in Port Erin Bay for the first time on November 9th, 1909. We also showed that it increased in numbers from 400 specimens on November 9th in the coarse net to 1,600 specimens in a haul with the same net on November 13th, and for the rest of the year the numbers varied from 1,000 to 800 for the coarse net. We then stated: "The view is definitely held by Ostenfeld that this is a "case of an exotic species which was introduced "accidentally (e.g. by a ship from the East) into "European waters near the mouth of the Elbe, probably "in September, 1903; and the rate of dispersal from that "point is used as an indication of the presence and rate "of flow of currents. If Ostenfeld is right in his "interpretation of the facts, then our record shows that "the species had extended to the centre of the Irish Sea "in 1909, and that here, as elsewhere, it reached a "maximum in November. It is, however, possible that "we have in all these records the unusual increase of a "rare species which had previously escaped observation."

The specimens of *Biddulphia sinensis* noticed during the first year of its occurrence in our area were single cells, as shown in figs. 1 and 2 on Pl. I. There was not the slightest indication of increase in numbers by cell division.

On p. 207 of the XIXth Annual Report (1910) we state: "The Indo-Pacific Diatom, *Biddulphia* "*sinensis*, which has appeared recently in our N.W. "European seas, is again present at Port Erin in "November in quantity.

"It seems now, from its appearance in the gatherings, to be in much more vigorous condition than when "it first occurred in the Irish Sea. The cells are seen "to be in active division, and chains of two and four "cells adhering together are quite frequently seen."

The general appearance of the dividing *Biddulphia sinensis* in 1910 is shown by fig. 3 on the Plate. It agrees fairly well with the text-figure given by Ostenfeld on p. 363 of the "Internationale Revue d. Hydrobiologie und Hydrographie," Bd. II, 1909. Up to this time all appeared to be well with *Biddulphia sinensis* in our district, and it was acting just as a sound species ought. It again made its appearance in the autumn of 1911, and for a time continued in a normal condition. Towards the end of that year, however, odd specimens were noticed which showed a departure from the true *sinensis* form, and appeared to be adopting some of the characters of *Biddulphia mobiliensis*. We state on p. 138 of the

XXth Annual Report (1911): "In our district "*B. sinensis* is of more elongated form than is shown in "Ostenfeld's figures. Most of our specimens of "*B. sinensis* are very distinct and easily distinguishable "from the *mobiliensis-regia* group by the shape and the "position of the spines, but we have found one or two "specimens during this last year where one end of the "cell bore the characters of *sinensis*, while the other had "the appearance of *mobiliensis*. Until, however, we get "further specimens we do not propose to base any "opinion as to the species upon this possibly abnormal "form. We are watching the fresh material of "*B. sinensis* carefully in the present year (1912), and "may return to the subject in our next report." We are now carrying out that intention.

The change in the stability of *Biddulphia sinensis* became more marked in the Bay gatherings taken in the early spring of 1912, and again in the Bay gatherings taken in December.

The appearance of the abnormal forms is shown by figs. 5, 7, 8, 9, 10, 12, 14 and 15 on the Plate. All these figures show clearly that one end of the cell is a *Biddulphia sinensis*, while the other end shows a decided approach to the appearance of *Biddulphia mobiliensis*. The spines have migrated away from the base of the continuation processes of the shell to nearer the centre. The concavity between the spines which is distinctly visible at the *sinensis* end has become almost obliterated at the *mobiliensis* end by the migration of the spines. The continuation processes have also suffered to some extent. They have disappeared entirely in figs. 7 and 9, and only one is left in figs. 8, 10, 12, 14 and 15. Most of the figures show the cell in the process of division. In some cases one of the daughter cells will become a typical

Biddulphia sinensis, as in figs. 6, 7 and 9. The other daughter cell in figs. 6 and 8 will apparently give rise to a cell very like the parent, and the ends will again be unlike. On the other hand, figs. 8, 10, 14 and 15 show that while one of the daughter cells may give rise to a *sinensis-mobiliensis* form, the other will produce a form closely approaching that of a true *mobiliensis*. Fig. 4 shows very distinctly two daughter cells of which the external ends are clearly of the *sinensis* type, but the internal ends where division is taking place are assuming a characteristic *mobiliensis* appearance. When division is completed we would arrive at the first stage of the transition of *Biddulphia sinensis* into *sinensis-mobiliensis*, then later at the next division probably we should have two apparently distinct Diatoms, *Biddulphia sinensis* and *B. mobiliensis*. We have noticed that when *Biddulphia* made its appearance in the autumn collections from Port Erin Bay during the last two years *B. sinensis* was at first the prevailing form. *B. mobiliensis* then becomes more plentiful later in the winter and in the following spring, when *B. sinensis* diminishes in numbers.

Gran, who reports on the pelagic plant life in "Depths of the Ocean," by Sir John Murray and Dr. Johan Hjort, refers to the known case of the Diatom *Rhizosolenia hebetata* occurring in two perfectly distinct forms. On p. 320 he describes the differences in the cell-walls and setae of *Chaetoceras decipiens* in spring and summer, and the variation in size and shape between specimens of *Biddulphia aurita* from along the Arctic coasts and off the south of Norway. He says: "We find "a variation of a different nature in the case of *Rhizosolenia hebetata*. It occurs in two perfectly distinct "forms, that were formerly regarded as good species.

"The first, which belongs to Arctic waters, is thick-"walled and gross, and is the true *R. hebetata.* The "second, *R. semispina,* has thinner walls and is pro-"portionately longer, and it is furnished with a long "hair-like point at each end. Its distribution extends "over practically the whole Atlantic, though it is chiefly "to be found in the neighbourhood of the cold currents. "These two 'species' can originate from one another "reciprocally as the result of one cell-division. During "the course of transition a cell may be *hebetata* at one "end and *semispina* at the other." This is just what we find is happening with our *Biddulphia sinensis.*

Biddulphia mobiliensis (Bailey), as figured by Ostenfeld in the volume of the "Internationale Revue" referred to above, is not nearly so common in the Irish Sea as the larger form he names *B. regia* (Schultze), and which we have all along recorded as *Biddulphia mobiliensis* (see figs. 16-19). We now regard it as probable that these three so-called species are all forms of the same Diatom in various stages of transition or modification. Bailey's name, *mobiliensis,* appears to be the older one, and ought to be adopted in preference to the others. For the sake of uniformity with the records in our previous reports, we continue to use the names *sinensis* and *mobiliensis* for the two forms shown in text-fig. 3 (p. 381), although we are not now inclined to regard them as being distinct species. They are, we consider, two forms (*B. mobiliensis,* forma *sinensis,* and *B. mobiliensis,* forma *regia*) of the original species *B. mobiliensis,* Bailey.

On the other hand, however, we are informed by Dr. E. J. Allen that he and Mr. Nelson succeeded at Plymouth in growing pure cultures of the forms *Biddulphia sinensis, B. mobiliensis* and *B. regia,* and that these retained their distinctive characters for over a year.

It may well be, however, that in the constant environment of a laboratory experiment a marked variation or "form," arising as a mutation, may continue to preserve its distinctive characters through many generations and appear to be stable; while under the varying conditions of a natural life in the open sea such marked variations may arise in some individuals, persist for a time, and then die out or be replaced more or less completely by one of the other forms. When examining a gathering such as we show in fig. 3 (p. 381), the forms *a* and *b* certainly seem very distinct; but on the other hand, the figures we give on Pl. I, like the cases quoted from Gran (in Murray and Hjort), do not seem explicable on the view that we are dealing with independent species. They may be regarded as mutations which under some circumstances breed true, but sometimes throw back to the original form of the species.

EXPLANATION OF PLATE.

Fig. 1. *Biddulphia mob.*, f. *sinensis*, as it first appeared in the Irish Sea in 1909.
Fig. 2. Ditto, a slightly elongated form.
Fig. 3. Ditto, normal division as it appeared in 1910.
Fig. 4. Ditto, transition form in process of development.
Fig. 5. Ditto, transition form after division and elongation.
Fig. 6. Ditto, normal but rather slender form dividing.
Fig. 7. Ditto, one end without continuation processes.
Fig. 8. Ditto, the form "*sinensis-mobiliensis*" dividing.
Fig. 9. Ditto, one end without continuation processes.
Fig. 10. Ditto, *mobiliensis* dividing.
Fig. 11. Ditto, slender but nearly normal form.
Fig. 12. Ditto, abnormal form.
Fig. 13. Ditto, probably a dead cell, showing divisions unusually near the end.
Fig. 14. Ditto, *mobiliensis* dividing.
Fig. 15. Ditto, *mobiliensis* dividing.
Fig. 16. *Biddulphia mobiliensis*, "regia" form of long shape.
Fig. 17. Ditto, "regia" form of short shape (turned sideways).
Fig. 18. Ditto, "regia" form dividing.
Fig. 19. Ditto, "regia" form dividing.
Fig. 20. Ditto, "regia" form approaching Ostenfeld's "*mobiliensis*."

Note the unusual number of spines in figs. 10, 12, 14 and 15. The figures are all photographs of equal magnification.

PLATE I.

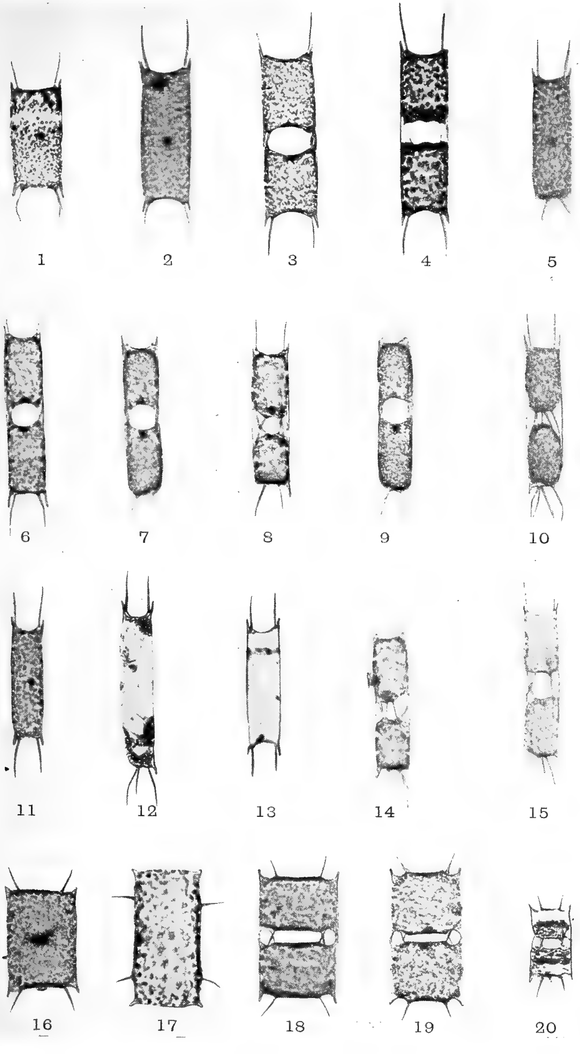

Photo. by A. Scott.

VARIATION IN BIDDULPHIA.

DINOFLAGELLATA.

The monthly averages for *Ceratium* and *Peridinium* throughout 1912 were as follows:—

1912.	Ceratium tripos.	Peridinium spp.	1912.	Ceratium tripos.	Peridinium spp.
January	3,977	36	July	1,318	1,367
February ...	1,211	62	August	98	208
March	11,510	0	September...	2,669	0
April	929	1,027	October ...	646	33
May	13,342	1,283,389	November...	5,157	229
June	1,014	23,000	December ...	1,096	176

The maximum in both cases is in May, a month earlier than in 1911. The numbers for *Ceratium tripos* were a little higher that year, but in 1912 *Peridinium* reached far higher numbers. In 1911 the maximum was only 38,000 (June 3rd), while in 1912 it was 8,650,000 (May 9th)—the greatest number of *Peridinium* we have ever recorded during these series of investigations. *Peridinium* is to be regarded as an oceanic form, and this exceptional abundance in 1912 agrees with other evidence that that year our western coasts showed an unusually large invasion of Atlantic organisms.*

NOCTILUCA.

We have remarked before (Part IV, p. 213) on the exceptional occurrence of *Noctiluca miliaris* in abundance off the Isle of Man in the late summer of 1910, and (Part V, p. 141) on its persistence in reduced numbers in Manx waters during practically the whole (10 months) of 1911. In 1912, again, this organism was well represented throughout the year, the only month

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* See also Herdman and Riddell on the Plankton of the West Coast of Scotland, elsewhere in this Report.

when we have no records of its presence in Port Erin Bay being April. The numbers usually vary from a few hundreds to a few thousands. On the whole, *Noctiluca* seems to be least plentiful in spring and early summer (February, March, April and May), and to become more abundant in autumn. Our largest haul is 16,400 on October 7th, and the next is 4,600 on November 16th, after which the numbers diminish to the end of the year.

COPEPODA.

We have again taken out the records of the nine commonest species of Copepoda, and have obtained the following results:—

*Calanus finmarchicus.**—This species is again present throughout the year, and in rather larger numbers than in 1911. One very high record is 50,720 on May 17th, and several hauls from one to over six thousand were taken from April to July. In October there is one large haul, namely, 2,120 on October 7th.

Pseudocalanus elongatus.—The highest record this year is 91,960 on October 21st; this is nearly twice as large as the highest in 1911. There is another, smaller, maximum in May to June, with 65,200 on May 20th and 44,500 on June 17th. Last year the maximum was in July, and there was no marked autumnal increase.

Oithona similis.—This is again the commonest species in our nets. The highest monthly average is 36,444 in June, but the two actually largest hauls are in autumn, 87,530 on September 26th and 75,400 on

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* We have sometimes in the past followed G. O. Sars in calling this species *C. helgolandicus*, but we are now inclined to agree with Wolfenden, Esterly, and others in thinking that the characters used in the attempt to separate "finmarchicus" and "helgolandicus" as species are too slight and inconstant—and so we return to the older name.

October 7th; these numbers were only exceeded in 1911 by the one enormous haul of 225,450 on July 18th.

Temora longicornis.—The distribution of this species again forms a simple normal curve, rising from an average of 4 in January and February to 17,000 in May, and sinking to zero in December. At the time of the maximum, which is earlier, the numbers are higher than in 1911. We find 50,400 on May 17th, followed by 83,400 on the 20th.

Paracalanus parvus.—The distribution of *Paracalanus* follows the same general lines as in previous years, having its maximum in September (49,390 on September 7th; 44,060 on October 24th) and its minimum in spring and early summer, during which time it is sometimes absent for periods of a few weeks.

Acartia clausi.—High numbers occur from May to October, some of the highest being 52,200 (May 20th), 41,950 (June 17th), and 59,490 (June 27th). The maximum appears to be earlier than in previous years.

Anomalocera pattersoni.—This species was again very rare, being present in only 14 of the Bay gatherings throughout the year. The greatest number were caught in April (180 on the 10th); and *Anomalocera* is entirely absent in six out of the twelve months.

Centropages hamatus.—This form appears first in March, increases to a maximum of 2,600 on May 17th, and dies down again by November.

Microcalanus pusillus.—The only records for this species this year are as follows:—April 9th, off Port St. Mary, coarse and fine nets together, 55; May 2nd, Bay, usual double haul, 30; August 7th, Bay, vertical net, 15; and December 30th, coarse net, 30—which is very remarkable considering that for the last few years the maximum of this irregularly distributed species has been in winter. The species is obviously a scarce one, which varies much in its occurrence from year to year.

The winter form, *Euterpina acutifrons*, was obtained in our nets from January (4,640 on the 4th) on, with decreasing frequency, to May 2nd, and it appeared again at the end of December. *Isias clavipes* occurred from May to November, with a maximum of 350 on August 15th. These records agree in general with those of previous years.

The monthly average hauls in Port Erin Bay for the eight more important species of Copepoda are as follows:—

	Calanus.	Pseudocalanus.	Temora.	Centropages.	Anomalocera.	Acartia.	Oithona.	Paracalanus.
Jan.	5	1,056	4	0	0	286	1,987	2,053
Feb.	4	446	4	0	0	41	1,978	493
Mar.	7	2,001	96	1	0	111	440	111
Apr.	530	1,060	384	17	43	410	766	0
May	6,716	11,899	16,999	342	23	10,850	7,708	274
June	459	14,599	2,191	19	0	20,390	36,444	0
July	739	4,987	3,628	61	0	6,578	16,404	232
Aug.	12	6,429	409	45	0	1,899	12,868	10,146
Sept.	129	4,027	136	61	6	6,148	21,284	14,363
Oct.	343	30,866	40	18	0	9,320	23,864	11,106
Nov.	47	3,196	11	2	0	584	5,995	4,241
Dec.	23	2,288	0	0	0	239	2,655	829

Although the highest averages do not in most cases coincide with those of the previous year, still the general course of the separate species throughout the year is fairly constant, and probably represents the normal.

The following diagram (fig. 4) shows the curves of the more important forms of Copepoda—the five most abundant in the table given below.

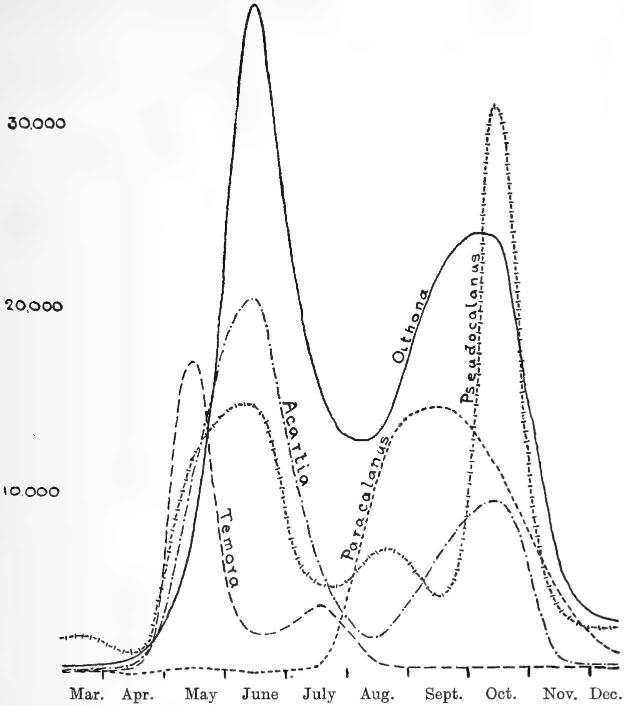


FIG. 4.—Five chief genera of Copepoda.

We repeat here the table given in last year's Report (p. 144) showing the total numbers of the six most abundant species of Copepoda, in the order of their abundance, for several years, with the numbers for 1912 (obtained from about 150 standard hauls) added:—

	1912.	1911.	1910.	1909.
Oithona similis	1,055,213	1,155,108	872,678	465,066
Pseudocalanus elongatus	643,466	365,983	386,326	309,973
Acartia clausi..................	450,778	323,633	340,631	63,373
Paracalanus parvus	363,881	351,088	217,633	54,120
Temora longicornis	210,542	106,359	147,043	62,659
Calanus finmarchicus	79,429	5,843	15,481	21,412

It is interesting to notice how these species almost invariably come in the same order year after year. This result tends to give one confidence that our methods are fairly reliable, and are leading us to what we may be entitled to regard as truths of nature, and not merely the hap-hazard outcome of experiments which might have come out differently had the experiment been performed otherwise. A primary purpose of plankton experiments under new conditions ought always to be to eliminate fallacies due to the artificial factors of the experiment and get down to the fundamental facts.

CLADOCERA.

In 1912 *Podon intermedium* first appeared in the Bay on March 8th, attained its maximum on May 17th (3,900), and died down by the end of October. The numbers are generally in the tens or few hundreds, so that one could rely upon catching, say, from 50 to 200 specimens in an average haul between April and September.

Evadne nordmanni was present from March 18th to August 1st, and reached its maximum at the same time as *Podon* with 7,900, and 6,500 a few days later. The usual hauls are of much the same character as those of *Podon*, but the occurrence is practically restricted to April, May and June.

Last year the maximum of both these forms was in September, and did not reach quite so high a point as in 1912. The group then is essentially a summer one, and in this locality seems to have been on the increase during the last few years. The difference, however, from year to year is not very striking, and the general form of the curve remains fairly constant. The Cladocera may be regarded as having their utility in nature in making a reliable and appreciable addition to the summer zooplankton. The nutritive value of the various forms in the plankton at the different seasons is a matter of great practical importance upon which we hope shortly to have fuller information.

SAGITTA.

Sagitta bipunctata was again present throughout the year, and had its maximum (over 2,000 on May 17th and 2,600 on May 20th) a little earlier than usual. The second increase, which in former years has taken place in October or November, was not manifest in 1912 until December (347 on December 23rd).

We feel, however, in regard to this organism that our Bay surface nets may fail adequately to represent the facts. It has been shown by E. L. Michael at San Diego, California, that *Sagitta* performs very considerable vertical migrations in the twenty-four hours, and tends to seek what are called "twilight conditions." It migrates to that zone in which the intensity of light is similar to that occurring during the day in from 15 to 20 fathoms, sinking before the brightest light, but rising also before the time of greatest darkness, and being most abundant on the surface during morning and evening twilight. So that horizontal hauls at various depths, such as we obtain with the weighted net, the shear-net and closing zone-nets, are necessary in order to sample adequately the *Sagitta* population.

It is evident from our work that this holds good for various organisms of the plankton—if not indeed for all, and that in the case of groups affected by light, temperature and other environmental influences there is an optimum which is neither the maximum nor the minimum.

OIKOPLEURA.

In 1912 *Oikopleura dioica* was again present in every month, and was unusually abundant. The numbers increased to thousands as early as March 4th, and the highest record was 57,860 on March 11th. The real maximum, however, appears to have been in September, when the monthly average was 11,593, as against 9,709 in March. The species died down again in November to hundreds and tens. In this there is no serious departure from the records of the last few years, so it may be taken as expressing in general the normal course of the organism.

VARIOUS LARVAE.

A number of different kinds of invertebrate larvae occur in considerable quantity in the Bay from time to time throughout the year, and must add appreciably to the nutritive value of the zooplankton. We shall note here only a few examples of these.

Echinoderm larvae are absent in January, but occur in numbers of between one and three thousand per haul on various occasions in February, and run up to 6,000 in March. After early April they die off, and are practically absent during the summer, but re-appear in September, reaching a maximum of 3,600 on the 20th.

Polychaet larvae are present in January, sometimes up to considerable numbers (2,420 on 4th), and become still more numerous in February (over 20,000 on 10th, 36,800 on 27th) and March (over 10,000 on 1st and 11,000 on 21st). In April the numbers drop to hundreds, in May again there is a slight increase to a few thousands, and that is the condition throughout the summer and autumn—and in fact, with occasional intervals, to the end of the year. The thousands are reached twice in December.

"Mitraria" larvae are abundant in the early part of the year and in autumn, and are absent throughout the greater part of the summer. Notable numbers picked out are 10,000 on January 4th, 5,000 on January 22nd, 4,000 on February 27th, 6,000 on March 8th, 3,000 on April 1st, and 2,000 on April 29th. Then comes the "off" season, till 2,900 on September 17th, 750 on October 7th, 420 on November 14th, and 520 on December 27th.

Crab Zoeas and Megalopas are not very abundant, but are probably of high nutritive value in the plankton. They do not in our hauls usually get above units and tens, rarely reaching one or two hundreds (200 on March 25th, 100 on May 2nd).

The Balanus nauplii began this year with 100 on February 1st and 1,200 on February 10th, nearly 10,000 on February 29th and 1,600,000 (the maximum) on March 11th. After which the numbers rapidly fell off during April, and reached units at the end of May. Of the "Cypris" stage comparatively few were present, appearing in small numbers early in April, increasing to 550 on May 17th, and then dying down to units again early in June.

Molluscan larvae were fairly abundant. Gastropod larvae appear late in January (1,000 on the 22nd, 900 on the 29th), and the next two months have each some hauls rising to over 1,000 (the highest is 1,600 on March 8th). In April and May the numbers are much less, and June shows none. They re-appear in force in July (4,000 on the 4th), and are fairly abundant during all the remaining months of the year, reaching thousands occasionally in most of them. The highest record is over

11,000 on November 7th. Lamellibranch larvae are even more abundant than Gastropods (nearly 18,000 on January 4th). Some hauls reach the thousands in each month of the year, and some of the chief hauls are as follows:—22,000 on May 20th, 16,000 on June 20th, over 41,000 on September 7th, 56,000 on October 7th, and 12,000 on November 7th. It is evident that several of these groups of larvae, in addition to a maximum early in the year, have a second climax in the late autumn.

MEDUSAE AND CTENOPHORA.

The Medusae are present in Port Erin Bay throughout the year. The numbers are low (only a few individuals in each haul) in January and February, then increase gradually to the maximum of 615 on May 20th, fall again in summer, rise to a second maximum at the end of September and beginning of October (380 on September 23rd; 406 on October 7th), and are again low till the end of the year.

Much work has still to be done in determining in detail the specific forms present at different times. Probably those of the May and September maxima belong to different sets.

Pleurobrachia, our commonest Ctenophore, occurs in nearly every month in the year, but especially in autumn (end of September and October), when it may add considerably to the bulk of the plankton, and be of real importance, not as a food-matter, but as an enemy or a competitor injuring forms more useful to man.

Our knowledge of the extent to which some animals in the sea prey upon others is still very incomplete and inexact. We have been constantly on the watch during these plankton investigations for any cases that would add to knowledge on this matter, but it is surprisingly difficult to catch organisms in the act of securing or swallowing food. Consequently the record we give in fig. 5 may be of interest. This is no accidental case of entanglement, but shows a Ctenophore drawing the Mysid into its widely-open alimentary canal.

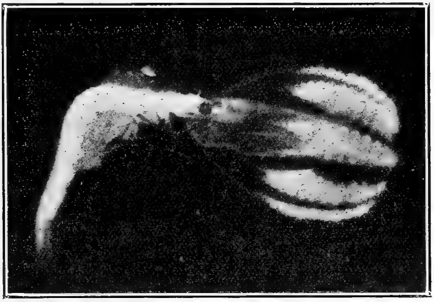


FIG. 5.—Ctenophore caught swallowing a Mysid.
[Photo. by A. Scott.

Probably both Ctenophores and Medusae are responsible for a considerable amount of destruction of young fish and Crustaceans during the year.

FISH EGGS.

On account of the special importance of the fish eggs and larvae of the plankton, from a Fisheries point of view, we have removed this section from the present more general paper, and the matter will be treated by Mr. Scott in a separate paper to follow.

We shall simply state here for the sake of continuity with former reports that:—

Rockling eggs were present from the end of January to the end of September, and the maximum was again in March, with an average of 85 per haul.

The other fish eggs ranged from the end of January to the end of July, with a maximum in March of 32 per haul.

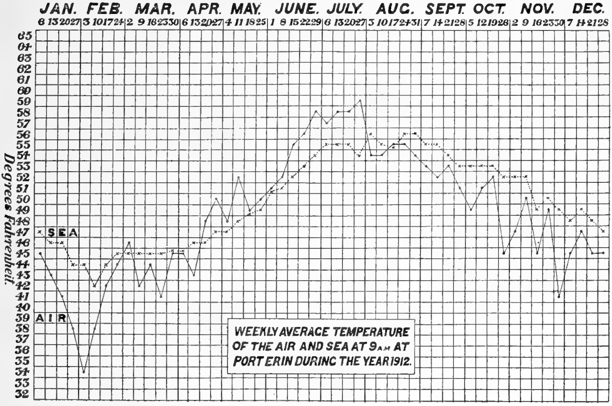
Some General Remarks.

It must be remembered that in the last few reports we have given little more than summaries of the results obtained for each group, and that we have now accumulated a very considerable mass of statistics, including the numerical details of each species in each haul throughout the successive years, all of which is awaiting further examination.

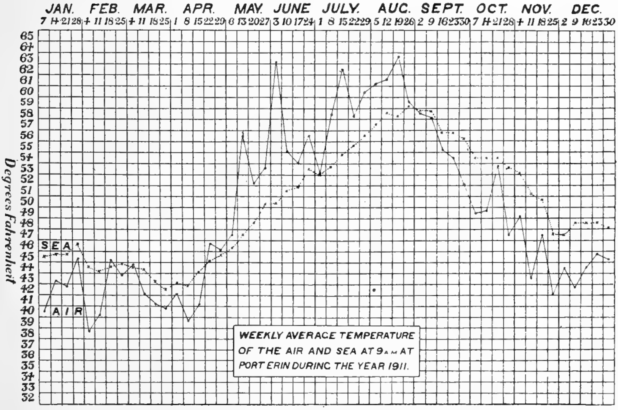
Among rarer, noteworthy forms that have occurred during the year are:—A Siphonophore (*Cupulita sarsi*) in January, and the unusual Copepoda, *Metridia lucens*, *Candacia armata* and *Corycaeus anglicus*, all of which are oceanic forms carried into our area from the Atlantic. *Metridia* occurs in no less than eight months, but with the exception of 153, on June 20th, it is never abundant. *Candacia* and *Corycaeus* occurred rarely.

Judging from the time of appearance and the maxima of most of the plankton groups, 1912 was an unusually early year. The Diatoms made their appearance in quantity earlier, and the maxima of the Dinoflagellates and the Copepods were about a month earlier than in 1911. Although 1911 had an unusually hot and dry summer, it was not until late in April that the temperature of the sea rose above 45° F., while in 1912 the sea-temperature was 45° or over from the end of February onwards.

The weather charts (prepared by Mr. Chadwick from his daily records at the Port Erin Biological Station) which are annexed show the contrast between the two years very clearly.



WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A.M. AT PORT ERIN DURING THE YEAR 1912.



WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A.M. AT PORT ERIN DURING THE YEAR 1911.

UTILITY OF PLANKTON INVESTIGATION.

1. The Modern Problem.—Many of the older naturalists worked at marine plankton qualitatively, and even connected the prevalence of certain organisms with the prosperity of sea fisheries; but modern instruments and methods of precision, such as might be expected to prove quantitatively the influence of variations in the type and amount of plankton, at different seasons and depths, upon the movements and abundance of fishes, have only been employed of recent years, and it is still too early to expect much in the way of demonstrated result.

Some data have been obtained which are full of promise for the future; but marine biologists investigating the plankton in recent years have rightly felt that their immediate duty lay in making detailed experiments at different localities and seasons, and under various conditions, in order to test and standardise their instruments so as to determine the causes and understand the meaning of the variations in their catches. There is still much to be done in the way of obtaining agreement as to the nets to be used and the methods of investigation of the catches to be adopted before the results from different localities can be compared.

2. Plankton as Food of Fishes.—Many commercial fishes feed upon plankton during at least some portion of their life. The Loch Fyne herrings are frequently, at the time of a fishery, found to have their stomachs filled with *Nyctiphanes*, *Euchaeta* or *Calanus*. In some parts of the Hebridean seas the herrings have their stomachs filled with the Pteropod *Limacina retroversa,* and other oceanic organisms which may be carried in swarms into our coastal waters. Many other similar cases could be quoted, and are known to biologists (see especially the works of Heincke, Moebius, Nordgaard, Pouchet, Murray and Hjort).

Then as to demersal fish—young plaice, after their metamorphosis, feed chiefly on Copepoda, while in younger stages the larval plaice feeds upon Diatoms. We have found at Port Erin the post-larval plaice with its stomach shining through of a golden-brown colour from the Diatoms with which it was filled, and one of us has watched in a shallow pond the metamorphosed small plaice darting backwards and forwards pursuing, catching and devouring the individual Copepoda. Then again it has been shown that these Copepoda in their turn feed on Diatoms, Dinoflagellates and Protozoa. So practically all the main constituents of the plankton are concerned in the nourishment of either young or adult fishes.

On the Lancashire coast we find the young plaice which are just appearing in the inshore nurseries have their stomachs filled with pelagic larval annelids.

The Pollan (*Coregonus pollan*) of Lough Neagh, in Ireland, has been shown to be on some occasions filled up with *Mysis relicta*, and at other times to be feeding solely on Cladocera; and there is reason to believe that the movements of the fish, which are extensive and periodic, can be definitely related to the presence and nature of the plankton.

Dr. Hjort has shown a correspondence between the distribution of the plankton-feeding whales (such as the Greenland whale) and the most abundant swarms of plankton at particular seasons. Prof. G. O. Sars and others, in tracing shoals of herring and cod in the North and West of Norway, have distinguished between the "feeding" migrations and the spawning migrations, and the feeding migrations depend upon the plankton.

3. Bearing of Putter's Views.—The experiments and arguments of Professor Pütter in regard to the nutrition of fishes and other aquatic animals need not lead to any change of opinion as to the economic importance of the plankton. If, as seems likely in the light of the recent experiments of Henze and B. Moore, Pütter's figures require considerable modification, then the argument as to the insufficiency of the plankton as a food material falls to the ground. But even if Pütter's figures are correct, or partly correct, that consideration must if anything lead to an enhanced estimate of the importance of the plankton from the fisheries point of view; as, if Pütter *has* shown anything new and true, it is that such an animal as a fish could not be nourished by the amount of plankton in the water if the material were merely strained out of the average water of the sea area in which the fish was living. In order to get an adequate quantity of planktonic food the fish must seek out and capture the Copepoda, for example, just as fish on occasions can be seen to do. In other words, the fish must go where the plankton is abundant, and must in its movements follow the movements of shoals of plankton. It is the very poverty of the plankton in some sea areas, insisted on by Pütter, Lohmann and others, which makes it necessary for plankton-eating fish to move about in search of more abundant supplies.

4. Association of Fish with Plankton.—This association of shoals of fish with abundance of plankton is in agreement with many observations that have been made by naturalists in the past. It is well known that in coastal waters favourite line-fishing localities are where strong tides run through narrow channels or over rocks and banks, and these are just the places where of recent years it has been found that plankton is also most abundant.

Any naturalist cruising on the West of Scotland (and no doubt in any other region where there are strong tides) could scarcely fail to notice the way in which the gulls and other sea-birds congregate where the currents run most strongly and where there are swirls in the water, indicating rocks or an uneven bottom, and resulting vertical movements of the water. These sea-birds are found to be feeding upon young fish, and the fish are there because the plankton is unusually abundant.

A definite connection seems to have been established on the coast of Cornwall, by Allen and Bullen, between the results of the mackerel fishery and the occurrence of *Calanus* in the plankton. There is some evidence that on the West coast of Scotland there is a similar connection between herring shoals and abundance of *Calanus*. The matter is well worthy of further investigation.

5. Plankton and Movements of Fishes.—Many groups of the plankton, and especially the zooplankton, it is now known quite definitely, are distributed in swarms, notwithstanding various assertions to the contrary. In our coastal seas at least, where the fisheries we are interested in take place, the plankton is *not* uniformly distributed. Various localities and depths are characterised at different seasons by particular assemblages of plankton, and it is reasonable to believe, in view of the facts given above as to the association of fish and plankton, that these variations in the distribution must have a marked effect upon the presence and abundance of at least such fish as herring and mackerel, and also of the shoals of post-larval young of many valuable demersal fishes.

There is a method about the detailed distribution of the plankton that convinces one it must depend upon laws or factors which can probably be ascertained, and thus lead to the possibility of correlation and prediction within limits.

That different currents or bodies of water in the sea differ very notably in their plankton is well known to biologists who have tested the matter. For example, in crossing the Atlantic to Canada one can tell to a nicety, even by means of a small silk net attached to a bath tap on a passenger steamer, when the ship has entered the Labrador current. The catch of plankton is suddenly increased enormously, and consists of an entirely different assemblage of organisms; and this abundant plankton is probably definitely related to the great fisheries on the Newfoundland Banks.

Observations in the Irish Sea and on the West of Scotland have shown that the plankton at a locality may fluctuate, both in amount and essential nature, from year to year; and although a definite relation between these fluctuations and the variations in the distribution and catches of fish has not yet been established, it is reasonably probable that a fuller and more detailed knowledge of both will enable a correlation to be demonstrated.

Artificial hatching, rearing and transplanting, if shown to be beneficial to the fisheries, must depend for success, in part, upon a knowledge of the plankton, for the young fish must obviously be set free where they can obtain their natural food.

6. Relation of Plankton to Hydrography and Fisheries.—It is clear then that there are definite relations between fishes and plankton organisms, and that it seems possible with fuller data to correlate some of the movements of fish with the distribution of plankton. There is thus a reasonable probability that an increased knowledge of the minute life of the sea may be directly useful in connection with the regulation of fishing industries.

The plankton in many cases seems to be the link between the hydrographic changes and the fisheries; but it must not be supposed that the plankton is in all cases definitely related to the hydrographic data, and that, therefore, a knowledge of the hydrography would suffice. Kofoid showed in 1903 (Plankton of Illinois River) that there are variations in the quantity of plankton which are independent of hydrographic and meteorological conditions. He says: "Somewhat regular alternations "of growth and rest, of fission and spore formation, or "of parthenogenesis and sexual reproduction, are "fundamentally the basis of cyclic movement in "[plankton] production. The *amplitudes*, and to some "extent the location and duration of the pulses, are "plainly affected by the various factors of the environ-"ment . . . by light, temperature, vegetation, tributary "water, various hydrographic factors, and by food "supply, and possibly, also, by chemical conditions not "directly concerned in nutrition, but the available data "fail completely to afford any satisfactory environ-"mental factor or group of factors which stands in "correlation, even remotely obvious with this cyclic "movement in production. I therefore class this "*periodic growth*, these *sexual cycles* which cause "volumetric pulses, under the head of internal factors. "The element of *periodicity* in itself does not seem to be "consequent upon any known external factor."

E. L. Michael (in his work on the Chaetognatha of San Diego, 1911) supports Kofoid's view as applying to both fresh-water and marine plankton,* and most planktologists will probably agree that there are such "internal factors" affecting the occurrence and quantity of the plankton independent of environmental or hydrographic factors.

The investigation of the plankton is a very special study requiring exploring vessels at sea, laboratories on shore and carefully trained biologists. Unlike the case of hydrography, no information in regard to this subject of investigation can be obtained from any other source. But, on the other hand, it can, and ought to be, closely associated with hydrographic observations and also with the statistics of commercial catches. Hydrographic observations and plankton samples and information in regard to the fishing in the locality ought all, so far as may be possible, to be obtained simultaneously.

7. The International Work.—The plankton portion of the original programme devised by the International Council entailed the quarterly collection (in February, May, August and November) of plankton at a number of fixed stations, by means of horizontal (at various depths) and vertical hauls with nets of various mesh. [The justness of the criticism then made that the quarterly intervals were too long, and the fixed stations too far apart, is now generally admitted.]

In August, 1909, the International Council resolved:—

(i) "That plankton samples should be collected by means of vertical hauls at certain definite places as often as possible (weekly or fortnightly), and that if research steamers were not available, observations should be made from lightships and inspection ships."

(ii) "That quantitative methods should be employed to a greater extent than formerly, that samples should

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* See also, Herdman in *Internationale Revue*, Bd. II, p. 124, 1909.

be measured volumetrically, and the larger organisms (Metazoa) counted."

It was also decided that the nets to be used for this purpose should be:—

(1) Medium Apstein, gauze No. 20 [180 meshes per inch] diameter of opening 16 cm.

(2) Nansen, gauze No. 3 [55 meshes per inch] diameter of opening 50 cm.

[All this was a distinct improvement on the original programme, but must be regarded as a minimum. Horizontal hauls should be added.]

In April, 1912, the International Council resolved: "That in addition to 'ordinary purposes'—

(i) "the principal aim and object of the plankton investigations with nets shall be to determine the entire life-history of a selection of the plankton animals which are most important as fish food, e.g., Copepoda [16 species named];

(ii) "with a view to determining the relation of plankton and fishes, simultaneous examination should be made of the stomach contents of pelagic fish and the plankton in the surrounding waters;

(iii) "it is extremely desirable that quantitative investigation should be made of the micro-plankton by Gran's method (samples collected by means of a water-bottle and preserved with strong Flemming solution);

(iv) "that (i) and (iii) should be begun in the May cruise, 1912."

[The determination of the life-histories of important organisms such as the 16 Copepoda named should no doubt be carried out, but it is said to involve over 200 separate forms, and so is a very large piece of work. It is quite a question whether it is the work that is most urgently required. No. (ii) is excellent; but why (see iv) should it not be undertaken with the rest?]

SOME CONCLUSIONS.

It is obvious that in correlating fish movements with plankton we must take into account both the volume and the composition or nutritive value of the latter; further work is required on this point. It is desirable that some general agreement as to methods of estimating volumes, and also of determining nutritive values, should be arrived at without delay, so that comparable data may be provided for the approximate estimation of fish food at different localities and seasons.

The methods of enumeration hitherto in use need not, however, be dropped. They may eventually prove to give results of value, and for the sake of continuity of observation it would be unfortunate if any gaps in the series of records were left.

In connection with the zonal distribution of plankton and the vertical oscillations, it is necessary to make horizontal hauls at various depths so as to determine the plankton contents of the different strata of water.

In addition to the minimum of observations required from our seas under the International organisation, it is most desirable that the observations carried out on our different coasts should be standardised under a national scheme of plankton research.

ON THE PELAGIC FISH EGGS COLLECTED OFF THE SOUTH-WEST OF THE ISLE OF MAN.

By Andrew Scott, A.L.S.

The following is a summary of the results of the investigation of the pelagic fish eggs that were found in the plankton from the area off the south-west of the Isle of Man between the beginning of 1907 and the end of 1912. There can be little doubt that many of the eggs collected had been spawned more or less continuously in the area between the limits recorded for each year. Their apparent spasmodic occurrence is probably due to a large extent to the drift of the water after the eggs had come to the surface. Sometimes they may be carried well inshore, even inside the breakwater where the bi-weekly collections are made throughout the year. At other times the eggs may be drifted out of the area altogether, and very few will be found in the plankton. It is also fairly certain that the eggs of some species of fish, which may not occur in the local fauna, will drift into the area from outside sources. It will be seen from the records that many of the fish may have a longer spawning period than was formerly suspected. This is fairly well shown in the case of the rockling and the dragonet. We have found dragonet eggs as early as January 23rd and as late as the beginning of August in hauls from places wide apart in the Irish Sea. This represents a general spawning period of about seven months for the dragonet, instead of from four to six months. Very few of the pelagic eggs have any marked character, apart from their size or the presence of an oil globule, by which they may be easily identified. The variation in the size of the eggs spawned by a single female fish is sometimes very great, and the extremes often overlap with those of other species of fish, therefore the identification of preserved material can only be approximate. The eggs of some species of fish, which are not recorded at all from the area although the adults are known to occur, may, from overlapping in size, be recorded along with the eggs of other species. The number of eggs present in a single surface sample is usually very small, and there is greater difficulty in separating out the various kinds than when large numbers can be dealt with. The identification of preserved specimens of young fish in their larval and post-larval condition is often almost impossible owing to the mutilation that takes place when they are captured, and any colour that may be present generally disappears in the preservative. After the post-larval stage is reached identification becomes more simple, but the young fish sink deeper down in the water and are not often captured by the ordinary surface nets. Young fishes, with the exception of rockling (or mackerel midges) and sprats, are seldom taken at the surface.

The arrangement of the fishes followed here is that adopted by G. A. Boulenger in the Cambridge Natural History, Volume VII.

Clupea sprattus, Linn.—Sprat.

The spawning period of the sprat, according to the records made during the six years' intensive study of the plankton collected at the south-west of the Isle of Man, extends from the beginning of April to well into September. In 1907 and 1908 the egg was only observed in one collection in each of these years, viz., April 2nd, 1907, and April 27th, 1908. Its first appearance in 1909 was on May 3rd. It occurred frequently throughout that month, but was not observed after June 19th. The records obtained during the years 1910 and 1911 are almost identical with each other. It was first noted on June 3rd, 1910, and disappeared after September 17th. The eggs occurred on June 5th in 1911, and were not observed after September 19th. They were present in every collection taken with the surface nets between the dates mentioned in each of the two years, i.e., a period of well over three months. The egg of the sprat did not make its appearance in 1912 until July 8th, and was not observed after the end of that month.

The pelagic larvae were not often met with in the plankton, but when present were usually more abundant at the end of April than at any other time covered by the spawning period. It appears rather strange that the larvae were more common in the plankton of the area in 1908, one of the years containing a single record of the egg, than in 1910 and 1911. A surface collection taken on April 22nd, 1908, contained 130 larvae, and another, taken on April 23rd, contained 329 larvae. Only four larval sprats were obtained in 1910, and these were from a collection made on September 16th. No larvae were observed during the whole of 1911. The larvae were not taken in the area after the end of September in any of the six years, although we have found post-larval sprats 18 to 25 millimetres in length in the plankton collected off the North Wales coast as late as the first week in December.

Gadus callarias, Linn.—Cod.

The pelagic eggs of this valuable food fish occur in the plankton of the area between the end of February and beginning of May. In 1907 the eggs were not observed until March 29th, and the last date on which they were present was April 27th. They appeared nearly a month earlier, March 4th, and disappeared after April 29th in 1908. The eggs were slightly later in making their appearance in 1909, and lasted a few days longer than in 1908. The first record was obtained on March 12th, and the last one on May 3rd. The year 1910 presented us with the earliest and latest records during the whole of the six years since the intensive study was initiated. The eggs were first noticed in plankton collected with the surface net on February 25th. They occurred frequently throughout March and April, and finally disappeared from the plankton on May 12th. The eggs of the cod were not observed in the plankton of 1911 until April 12th, and none were noted after the end of that month. In 1912 the eggs occurred in the plankton collected on March 4th. They were present throughout the month and during the whole of April. The last record was obtained on May 9th.

Gadus aeglefinus, Linn.—Haddock.

The pelagic eggs of the haddock were only observed in the plankton collected during the first four years of the intensive study investigations. None have been obtained since 1910. This is due to the almost entire disappearance of the fish from the centre of the Irish Sea which took place about that time. The Fisheries steamer was able to collect mature haddock from the fishing grounds between Lancashire and the Isle of Man for dissection in the fishermen's classes for some years after their establishment at Piel, but the fish has been unobtainable for three years, and whiting have to be used instead. From the limited data available, we find that the spawning period extends from the beginning of March to about the middle of May. The eggs were first obtained in 1907 from plankton collected on March 29th. They occurred in most of the surface samples taken in April, but none were observed that year after April 26th. No haddock eggs were observed until April 7th in 1908, which is the latest first occurrence during the four years. They were present in most of the surface samples from that date onward to May 20th, but after that none were observed. Their presence in the plankton of 1909 was limited to a period of about three weeks. They were first noted on March 27th, and disappeared after April 14th. The year 1910 presented us with the largest number of records and also the longest period of occurrence in the plankton of the area. The eggs were observed as early as March 11th. They were present for fully seven weeks, and finally disappeared from the plankton on May 22nd.

Gadus merlangus, Linn.—Whiting.

The pelagic eggs of the whiting occur in the plankton off the south-west of the Isle of Man between the end of February and latter part of May. The appearance of the eggs during the last week of February is probably exceptional, as they were only observed in that month once in the six years. The normal time is evidently about the end of the first week in March. The eggs were found in the plankton as early as February 26th in 1907. Very few were observed in the March collections, but they were fairly prevalent during the month of April. The last record for the year was April 27th. In 1908 the eggs were first obtained from plankton collected on March 13th. They were present during the remainder of the month and throughout the whole of April. Whiting eggs continued one of the constituents of the plankton until May 12th. The eggs were much later in making their appearance in 1909 than in any of the other years during the intensive investigations. They also remained longer. Whiting eggs were not observed before March 26th. They were present in the plankton throughout April, and did not finally disappear until May 24th. In 1910, they were noted for the first time on March 11th, and continued in the area till the end of April. The occurrence and duration of the eggs in 1911 and 1912 were identical. Whiting eggs were first observed on March 4th, and were one of the constituents of the plankton till the end of April in each of these two years.

Gadus pollachius, Linn.—Pollack.
Gadus virens, Linn.—Green Cod, Coal Fish.
Gadus minutus, Linn.—Poor Cod.
Gadus luscus, Will.—Bib.

The pelagic eggs of the pollack, green cod, poor cod and bib are certainly represented in the plankton collected in the area from the end of January to the end of May. The difference in the size of the eggs of these four species of Gadoids is so very small that it is quite impossible to separate the four kinds when preserved. In fact one cannot be quite certain even in differentiating whiting eggs correctly from the eggs of the four species mentioned above. It is well known that all the eggs spawned by a female fish are not exactly the same size. There may be a difference of at least one-tenth of a millimetre between the largest and smallest eggs of a single fish. This difference may be increased to three-tenths of a millimetre when the eggs of a number of the same species of fish are investigated. The range in size of the eggs of one species of fish may easily overlap the measurements of the extremes in the case of another species. We find that the largest egg of the poor cod is slightly larger than the smallest egg of the whiting.

A. E. Hefford, in his report on the teleostean ova and larvae observed at Plymouth,* shows very clearly, from comparisons of the egg measurements of four species of Gadoids, the uncertainty in correctly identifying some of the pelagic fish eggs. The following table gives the variation in size of the eggs of four common members of the Gadoids and the size of the green cod egg, another member of the same family, for comparison.

Poor cod eggs	0·95—1·07 mm.
Bib eggs	1·05—1·15 mm.
Pollack eggs	1·13—1·14 mm.
Whiting eggs	1·069—1·352 mm.
Green cod eggs ...	1·161 mm.

The larval stages of the economic Gadoids found in the Irish Sea occur in the area covered by the intensive study investigations as early as the end of February. The post-larval forms are found up to the end of May, after which they probably sink below the surface and are not captured by the surface nets. Preserved specimens of the very young stages of Gadoids have a considerable resemblance to each other. They are easily mutilated in capture, and cannot often be identified with certainty.

Molva vulgaris, Fleming.—Ling.

The characteristic pelagic egg of the ling, which has a large smoky oil globule measuring 0·4 mm. in diameter, was only found once in the plankton collected at the south-west of the Isle of Man during the six years' investigations. It occurred in a surface collection taken on April 27th, 1908. The egg is comparatively small, measuring about 1·08 mm. in diameter, and the oil globule occupies fully one-third of the interior.

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Onos spp., Risso.—The Rocklings.

Two species of rockling are known to occur in the Irish Sea, *Onos mustela,* five-bearded rockling, and *Onos tricirratus,* three-bearded rockling. The former is the species most frequently met with, and is probably the one generally represented by eggs and young stages in the plankton of the area. The third species, *Onos cimbrius,* four-bearded rockling, may also occur, although it has not been recorded by any observer from the central area of the Irish Sea. The summary of the results of the six years' investigation of the plankton from the south-west of the Isle of Man shows that the eggs belonging to one or other of the two species first mentioned may be present in the plankton throughout almost the whole year. The spawning period of the five-bearded rockling, according to McIntosh and Masterman,* lasts from April to August, and the three-bearded rockling from November to January. The size of the egg of the five-bearded rockling, according to these authors, is 0·72 mm., and the oil globule 0·0825 mm. The egg of the three-bearded rockling measures 0·74 mm. and its oil globule 0·218 mm. The only difference, therefore, between the eggs of the two rocklings is in the size of the oil globules. In 1907 rockling eggs were present in the plankton from February 5th to September 19th, with the exception of July, when none were observed. The eggs occurred from January 4th in 1908 to August 7th without any interruption. In 1909 they were present almost continually from January 2nd to September 21st. The distribution during 1910 was much the same as in 1909, except that they persisted for nearly three weeks longer. The eggs were first noted on

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* British Marine Food Fishes. London, 1897.

January 3rd, and were present every month till October 10th. In 1911 the eggs occurred from January 9th to September 10th. They disappeared after that date, but were again present on December 29th. Although rockling eggs were obtained on December 29th, 1911, they were not observed in 1912 earlier than January 26th. After that date they occurred throughout each month till September 7th. The only month in the whole period of the six years' investigation in which no rockling eggs were observed was November.

Young rockling or mackerel midges from 10 to 20 mm. in length are frequently captured in the surface nets in various parts of the Irish Sea between the beginning of July and the end of August.

Ctenolabrus rupestris, Linn.—Jago's Goldsinny.

A very small egg (0·8 mm. to 0·9 mm.) with transparent yolk and no oil globule has been identified as belonging to Jago's goldsinny. It generally occurs in the plankton of the area in small numbers between the beginning of June and the end of September. In 1907 the eggs were found in the collections taken between August 13th and the end of September. It is the only year during the period of intensive investigations in which the records show it to have been not uncommon. It was only observed on June 6th and August 6th in 1908. No records at all were obtained for 1909. It was present in the surface collections taken on August 10th and 12th in 1910, but apparently not at any other time. 1911 was also a blank year, and not a single specimen of the egg was obtained. It occurred once in 1912 in a surface collection taken on August 9th.

Scomber scomber, Linn.—Mackerel.

The only record of the occurrence of the pelagic egg of the mackerel in the area was obtained from a surface collection taken on June 3rd, 1912. This is rather surprising, as the fish is very abundant some years in the whole of the Irish Sea. They are sometimes so plentiful that they can be captured inside Port Erin Bay and in Barrow Channel off Piel Island. Many samples of mackerel caught in the Irish Sea off Walney early in July have been examined in the laboratory during the last dozen years, but in no instance have we found mature reproductive organs. They are nearly always in a spent condition. The eggs are not uncommon in Cardigan Bay plankton collected at the beginning of July, and it is possible that the majority of the fish that arrive in the central area spawn on the way up from the south. If this be so, then the larvae would have hatched before the eggs could reach the south-west area off the Isle of Man, unless there should happen to be an exceptionally strong drift of the surface waters from the south due to long-continued southerly winds.

Drepanopsetta platessoides, Fabr.—Long Rough Dab.

The characteristic pelagic eggs of the long rough dab are only occasionally met with in the south-west area off the Isle of Man. The egg can be readily identified by the marked space between the yolk and the shell, which gives it an appearance resembling a double egg, a small one inside a larger one. Mature fish are captured nearly every spring between February and April on the off-shore fishing grounds to the north of Morecambe Bay light-vessel by the Fisheries steamer when fishing for material for investigation in the fishermen's classes. The spawning period probably extends from the middle of March to the end of April. The egg occurred twice in the plankton collected during 1907; first on March 29th, and again on April 10th. In 1908 only one record was obtained, and that was from a surface collection taken on April 14th. The eggs were present in the plankton of 1909 from March 27th to April 24th. They were observed in surface collections taken on March 27th, April 6th, 10th, 15th, 19th and 24th. The eggs were not captured in any of the collections made during 1910, 1911 and 1912.

Psetta laevis, Rondel.—Brill.

Small and half-grown brill are not uncommon in various parts of the Irish Sea, but full-grown mature specimens are not often met with. The pelagic eggs of the fish appear to be very rare in the area off the south-west of the Isle of Man, as it only occurred once in the plankton collected during the whole six years. The single record was obtained from plankton collected on April 1st, 1907. On that date it was found to be present both in Port Erin Bay and also in the open sea. A single specimen of a recently hatched larva identified as a larval Rhomboid was captured in the surface net on May 2nd, 1910. The eggs are occasionally found in plankton collected in Carnarvon and Cardigan Bays in the early part of July.

Zeugopterus punctatus, Bl.—Muller's Top-knot.

The pelagic eggs of one of the top-knots, which is probably the above species, are occasionally met with in the plankton from the south-west area off the Isle of Man between April 1st and July 1st. Muller's top-knot is the one generally captured when trawling is being carried on in the central area of the Irish Sea. Adult specimens of the Norwegian top-knot are very rare, but the small size of the fish may prevent its capture by ordinary trawling methods. Top-knot eggs were present in Port Erin Bay and in the open sea surface plankton from April 1st to 27th in 1907. The records obtained from the plankton collected in 1908 showed that the eggs were present for nearly three months. The first eggs were observed on April 2nd, and they did not finally disappear until June 27th. The majority of the surface collections taken during that period contained at least one or two top-knot eggs. The occurrences were more limited in 1909. The eggs made their appearance on April 6th, and were not seen after the 14th of that month. No top-knot eggs were observed in the plankton of the area in 1910 and 1911. They were only present once in 1912, and were represented in a surface collection taken on July 1st. The only larval top-knot that was observed during the whole of the six years' investigations was captured in the surface net on July 4th, 1912.

Lepidorhombus megastoma, Donov.—Megrim.

The pelagic eggs of the megrim or sail-fluke are frequently captured by the surface nets in the area off the south-west of the Isle of Man from March to the end of May. The adult fish are fairly plentiful on the west and south-west of the island in the deep water, where the bottom consists of very soft mud. Spawning females have been trawled there occasionally by the Fisheries steamer when carrying on special investigations for the purpose of locating the spawning grounds in the Irish Sea, in the early days of our scientific work. In 1907 the eggs were present in the plankton collected on March 29th and onwards until April 27th. The distribution in 1908 appeared to be rather limited. The eggs were not observed before April 15th, and none were present in the plankton after April 29th. In 1909, they first appeared on March 27th, and were frequently captured throughout April. The eggs remained one of the constituents of the plankton up to May 24th. The first eggs obtained in 1910 were found in a surface collection taken on April 8th, and were represented in the plankton from that date onwards until May 31st. This is the latest record in the whole of the six years' intensive study investigations. The distribution of the eggs during 1911 was restricted to about a month. None were observed in the plankton before April 12th, and they finally disappeared on May 15th. We obtained the earliest record of the occurrence of the eggs during the six years' plankton investigations in 1912. The first eggs were captured on March 4th. They were present almost continuously from that date onwards until May 9th. Over 400 eggs were obtained from seven hauls with the shear-net in the open sea at Stations I and III between April 12th and 27th. No larval or post-larval stages that could be identified as young megrims were observed during the investigations.

Pleuronectes platessa, Linn.—Plaice.

The pelagic eggs of the plaice, which can be readily recognised by their large size, corrugated shell and absence of oil-globule, occur in the plankton of the area investigated during the intensive study from February 9th to April 23rd. The first eggs observed in 1907 were found in a surface collection taken in Port Erin Bay on February 22nd. They were noted again on March 6th, and in the plankton of the open sea on April 1st, 4th and 5th. The eggs appeared to be generally distributed in the Bay and open sea from March 13th to April 23rd in 1908. This was the latest date on which plaice eggs were found during the six years. The larvae were well advanced and nearly hatching. In 1909 the first eggs were observed on February 18th in the Bay plankton. They were generally distributed in the Bay and open sea throughout April and on to May 8th. The occurrences in 1910 were spread over a period of about two months. The eggs were present in seven collections taken in the Bay and in the open sea between February 28th and April 22nd. The plankton of 1911 gave us the earliest record of plaice eggs in the area during the six years. The eggs were taken in the surface plankton collected on February 9th and again on the 13th. They were only observed once in March, on the 7th. The plankton collected from April 4th to the end of that month showed that the plaice eggs were generally distributed in the Bay and in the open sea. The surface plankton collected on March 4th contained the first eggs observed in 1912. They were present from that date onward to April 15th. Larval and post-larval pleuronectids were frequently captured in the surface plankton between March 11th and the end of April during the six years' investigations, but they were generally too much mutilated to identify correctly. One post-larval plaice, 8·8 mm. in length, was taken in the surface net on April 1st, 1907. The stomach contained a single copepod nauplius.

We have found eggs of plaice in the plankton collected in Cardigan Bay near the Patches Buoy off Aberystwyth in December and January.

Pleuronectes limanda, Linn.—Dab.

The eggs of the dab, which are about the smallest that are met with in the plankton collected during the spring months, appear in the area off the south-west of the Isle of Man from the middle of February to the beginning of June. They occurred in Port Erin Bay on February 22nd, 1907. None were met with again until they appeared in the open sea plankton on March 29th. The eggs were generally distributed in the Bay and open sea throughout April up to the end of the month. Eggs of the dab were observed for the first time in 1908 in the plankton collected on March 11th. They occurred in most of the collections taken in April and May, and were present up to as late as June 6th. The eggs made their appearance in the plankton of 1909 on March 12th. They were fairly uniformly distributed in the Bay and in the open sea from that date onwards until May 17th. Very few records of dab eggs were obtained from the plankton collected in 1910. They did not occur before May 2nd, and none were seen after the 9th of that month. 1911 presented us with the earliest record of the appearance of the dab egg in the plankton of the area collected during the six years' investigations. The first eggs of the fish were found in a Bay collection on February 17th. None were observed again until March 4th. After that date dab eggs continued to be represented up to the end of April. The eggs occurred in the plankton collected during 1912 for a period of six weeks. They were noted for the first time on March 4th, and were generally distributed in the Bay and open sea from that date onwards to the middle of April.

Solea lutea, Risso.—Solenette.

Small pelagic eggs, measuring 0·76 to 0·8 mm. in diameter with many oil globules, which were identified as those of the solenette, were occasionally observed in the spring and early summer plankton of

1907 and 1908. They were present in the open sea plankton collected on March 4th, 1907, and again between April 15th and 25th. A few more were found later on in the plankton taken between July 12th and 31st. Only one record was obtained in 1908, and that was from a collection made on March 11th. None were noticed in any of the next four years' catches. The oil globule in the egg of the rockling sometimes splits up into a number of smaller ones when the egg is just spawned, but these small globules again fuse into one soon afterwards. It is just possible, therefore, that the eggs we identified as those of the solenette were really the newly spawned eggs of rockling. The characteristic egg of the sole was not noticed in any of the plankton collections taken in the area during the whole of the six years, but we have found them occasionally in the surface plankton from other parts of the Irish Sea.

Trigla gurnardus, Linn.—Grey Gurnard.
Trigla cuculus, Linn.—Red Gurnard.
Trigla lucerna, Linn.—Yellow Gurnard.

The pelagic eggs of the above three species are almost certainly present in the plankton from the south-west area off the Isle of Man from the end of March to about the latter end of August. There is considerable overlapping in the diameter of the egg and the oil globule of the three species, and it is almost impossible to state definitely which one may be represented at any particular time. The following table, which has been summarised from A. E. Hefford's report in the Marine Biological Association Journal already referred to, shows the amount of variation in the size of the eggs and oil globule of the three gurnards mentioned.

Grey Gurnard egg 1·163—1·55 mm., oil glob. 0·25—0·33 mm.
Red Gurnard egg 1·45—1·61 mm., oil glob. 0·28—0·33 mm.
Yellow Gurnard egg 1·1—1·7 mm., oil glob. 0·22—0·29 mm.

Gurnard eggs were observed in the plankton collected between April 1st and 27th in 1907. Only one record was obtained in 1908, and that was from a tow-netting taken on April 23rd. The eggs were noticed as early as March 29th in 1909, and from April 7th to 24th. Gurnard eggs were more plentiful in the plankton collected in 1910 than in any of the other years since the intensive investigations commenced. They were generally distributed from May 23rd to the 31st. A few were found on June 3rd and 7th, and again on July 14th. Surface collections taken on August 8th, 13th, 22nd and 23rd also contained pelagic eggs which were identified as *Trigla* sp. In 1911 the eggs occurred on April 27th, May 8th, June 4th and August 14th. The eggs found on August 14th measured 1·45 mm. in diameter, and the oil globule 0·32 mm. These were probably the eggs of the Red Gurnard. Only one record was obtained in 1912, and that was from plankton collected on June 20th. Some doubt was felt from time to time that possibly the summer eggs identified as gurnard might be those of the mackerel, but the colour of the oil globules was quite distinct. The oil globule in gurnard eggs is usually red or somewhat smoky looking, and the oil globule in the mackerel egg is greenish-yellow. The mackerel egg measures 1·22 mm. in diameter and the oil globule 0·32 mm., which quite corresponds with the sizes given above for gurnard eggs.

Callionymus lyra, Linn.—Dragonet.

The very easily recognised egg of the dragonet appears to be generally distributed in the south-west area off the Isle of Man from about the end of February to the first week in August. It probably occurs even earlier than the end of February, as we have found it in plankton collected in Ramsey Bay on the north-east end of the Island on January 23rd. The eggs occurred in Port Erin Bay on February 26th in 1907, which is the earliest record obtained during the six years' investigations. It was noted in the open sea on March 7th. The eggs were generally distributed in the Bay and in the open sea during the whole of April. It was observed for the first time in 1908 on April 2nd, and was present throughout the month. It only appeared once in May, and that was on the 26th, when forty specimens were found. The eggs were generally distributed in the Bay in June. It was captured on July 14th, and again on August 7th. The first record for 1909 was obtained from plankton collected in the Bay on March 5th. The egg was very rarely absent from that date onwards to June 25th. It appeared on March 15th in 1910, and was generally distributed to the end of April. The eggs only occurred once in May, on the 26th, but they were noted in the collections taken on June 3rd, 11th and 24th, and on July 8th, 14th and 26th. Dragonet eggs were first obtained on March 2nd in 1911. They did not occur again until April 10th, and were present during the remainder of the month. None were taken after May 1st. The eggs were more uniformly distributed in 1912 than in 1911. They were present in the plankton of the Bay and open sea from March 4th right on to June 3rd. Four hauls made with the shear-net at Station III on April 12th, 18th, 19th and 22nd contained 141 eggs. The haul on the 12th April captured 73 of this total. Although the dragonet eggs may disappear from the plankton collected off the south-west of the

Isle of Man at any particular time in the year, it does not necessarily follow that they will also be absent from the general Irish sea plankton after they cease to occur in that area. The last recorded eggs from the area in 1912 were taken on June 3rd, but they were present in the plankton collected in Carnarvon Bay on the 2nd and 3rd of July. McIntosh and Masterman state that the dragonet appears to spawn from May to August. Ehrenbaum, in "Nordisches Plankton," says that it spawns continually from April to August. In the English Channel it spawns from January to June. From the records above, we can safely state that the dragonet is spawning in some part of the Irish Sea from the middle of January to the beginning of August.

The following lists give a summary of the results of several hauls with the shear-net at Stations I and III in the south-west area off the Isle of Man in April, 1912.

	Station I. 3 hauls, April 13, 15 and 17		Station III. 4 hauls, April 12, 18, 19 and 22	
EGGS—	Nos.		Nos.	
Cod	756		423	
Whiting	861		797	
Green Cod	329		206	
Bib	571		461	
Rockling	119		140	
Plaice	—		1	
Sail Fluke	271		167	
Dragonet	42		141	
LARVAL FISHES—	Nos.	Length.	Nos.	Length.
Post Larval Gadoids	33	2—9·5 mm.	87	3—8·5 mm.
,, ,, Pleuronectids	1	7·5 mm.	8	5—8 mm.
,, ,, Butter fish (Pholis)	31	6—15 mm.	46	6·5—21
,, ,, *Cottus* sp.	4	4·5—7 mm.	4	5·5—6·5
,, ,, *Liparis* sp.	—		1	7·5
Larval Gadoids	1		—	
,, Pleuronectids	1		1	

Pelagic Fish-eggs and Larvae Found Elsewhere in the Irish Sea.

The wider investigation of the pelagic eggs and larvae of the Irish Sea, which forms part of the scheme of operations now conducted with the aid of the grant from the Development Commissioners, was commenced in July, 1912. It took some time to secure the various surface nets after the notification of the grant had been received, and the season was then too far advanced to make much progress. Everything is in readiness for the work in 1913.

The following tables give the results of surface hauls in Cardigan and Carnarvon Bays in July, 1912, which were the only places where eggs and larvae were fairly plentiful.

	Cardigan Bay, 7 hauls, July 3 and 4.		Carnarvon Bay, 3 hauls, July 2, 3 and 5.	
Eggs—	Nos.		Nos.	
Sprat	2		10	
Anchovy	3		—	
Rockling	3		2	
Goldsinny ...	27		—	
Mackerel	93		5	
Sole	283		4	
Topknot	38		—	
Brill	1		1	
Dragonet	—		2	
Post Larval Fishes—	Nos.	Length.	Nos.	Length.
Sprat	82	5—25 mm.	25	6—12 mm.
Garfish	8	9—14 mm.	2	9 mm.
Rockling	—		82	5—16 mm.
Lemon Sole ...	2	5·5—8·5 mm.	2	8—10 mm.
Sole	—		2	7 mm.
Topknot	—		1	4 mm.
Brill	7	4—5 mm.	—	
Gurnard	6	5—11 mm.	2	5·5 mm.
Dragonet ...	4	6—8·5 mm.	2	7—10 mm.
Pipe Fish ...	3	20 mm.	—	
Labrus sp. ...	35	5—9 mm.	—	
Gadoids	—		15	5—13 mm.
Whiting	1	30·5 mm.	—	

The occurrence of the pelagic eggs of the anchovy in July, 1912, is the third time we have found them in Cardigan Bay. The two previous records were obtained from plankton collected in 1906. The first was from a collection taken on June 14th, and the other on July 23rd. The late R. L. Ascroft found them in plankton collected off Lytham in 1896.*

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* Reports Lancashire Sea Fisheries Laboratory, No. **XV**, for 1906 (1907), p. 92.

DECAPOD LARVAE IN THE IRISH SEA.

By H. G. Jackson, M.Sc.

I. Material Examined.

This paper is a preliminary statement of the work carried out on Decapod larvae in the L.M.B.C. district. The material which has been investigated so far has been obtained in the tow-nettings which were taken by Prof. Herdman from his yacht "Ladybird" during 1907, along with those collected in Port Erin Bay during those months of the year in which the yacht was not in use. The similar nettings of years since 1907 have been examined for supplementary evidence of the distribution and occurrence of the larvae. Such larvae are rarely present, in any but very small quantities, in the surface tow-nets, so the deeper hauls of the shear-net have been principally relied on for furnishing a reasonable indication of the young stages of Decapod larvae met with in this portion of the Irish Sea. In consequence of this, the records of the Bay hauls are unreliable and fragmentary, and complete data are only obtainable for the spring and autumn months—the periods in which the yacht was at work. The gaps in these records are only partially filled by the similar work carried on from the Lancashire Sea Fisheries steamer, "James Fletcher," owing to the fact that these latter investigations are conducted in very different areas from those worked by Prof. Herdman, so that, although use has been made of this material, the data has not been included in the table that follows:—

II. LIST OF LARVAE FOUND.

Larva of	Date of Appearance. (1907)	Stage.	Distribution.	Relative Abundance
Portunus depurator	April 23	1st, 2nd	W. Calf	c
Do.	Aug. 13, 21	1st	P. Erin Bay	c
P. holsatus	April 8 and 9	1st, 2nd	10 m. N.W. P. Erin	r
Do.	Aug. 21	5th	P. Erin Bay	r
P. puber	April 8 and 26	2nd	10 m. & 5 m. N.W. P. Erin	c
Do.	Aug. 13 Sept. 20	5th	P. Erin Bay	c
Hyas araneus	April	1st, 2nd, 3rd	Off P. Erin	c
Pilumnus hirtellus (?)	April 18 and 26	—	Calf and 5 m. off P. Erin	+
Do.	Aug. and Sept.	—	Off P. Erin	c
Pinnotheres sp. (probably *veterum*)	Aug. 13	—	Niarbyl Point	r
Munida rugosa	April	1st, 2nd, 3rd	Off P. Erin	+
Galathea sp.	April 10-26	—	Off P. Erin	c
Do.	Aug.	1st, 4th	Off P. Erin	c
Do.	Sept.	1st, 3rd, 4th	Off P. Erin	cc
Eupagurus bernhardus	April	All stages	Off P. Erin	cc
Do.	Aug.	—	Off P. Erin	rr
E. prideauxii	April 8	1st	10 m. N.W. P. Erin	rr
Do.	Aug., Sept.	All stages	Off P. Erin	c
"Glaucothoe."	Aug.	—	Off P. Erin	r
Spiropagurus sp. ?	Aug.	1st ?	Off P. Erin	rr
Porcellana longicornis	Aug.	—	Off P. Erin	cc
Do.	Sept.	—	Off P. Erin	+
Crangon vulgaris	April	All stages	Off P. Erin	c
Do.	Aug.	All stages	Off P. Erin	+
Nephrops norvegicus	April	1st, 2nd	——	+
Pandalus brevirostris	April 23-26	4th	W. Calf and Bay	c
Do.	Sept.	4th, 6th	——	c
P. montagui	April 23	—	W. Calf	r
Hippolyte varians	April 24	3rd	Bay	+
"Lobsterlings"	Aug., Sept.	(4th)	Off P. Erin	+
Euphausids (*Thysanoessa* or *Meganyctiphanes*)	April	Calyopsis	Off P. Erin	cc
Unidentified Macrurans—				
[M1]	April 23, 26 Sept. 20	Several stages do.	Calf Is., P. Erin Bay Off P. Erin	+
[M2] (Pandalid ?)	April 23, 26	do.	Calf Is., P. Erin Bay	+
[M3]	Aug. 13	do.	Off P. Erin	+
[M4]	Aug., Sept. 20	do.	Niarbyl Pt. and Bay	c
[M5] (Hippolytid ?)	April 8, 9, 23	do.	10 m. & 3 m. off P. Erin	c

III. General Considerations.

The above list of zoeas and other larval stages of Decapods is more notable for its relatively small extent than for any great abundance of forms.

Perhaps the most striking omissions (not of an artificial nature, due to the removal during previous examination of some of the larger forms, such as Megalopa) which will be noticed in the lists are the young stages of two common crabs in the Irish Sea, *Cancer pagurus* and *Carcinas moenas*. Not a single representative of the latter species, the common shore crab, was found in the tow-nettings, and the former was only doubtfully present in the 1st zoea stage on the 13th of August. This absence is probably due to the fact that both these common species spawn in the late spring or summer, and that they both spawn close in-shore. For it must be remembered that the greater part of the most prolific material was taken in early spring or late autumn in localities several miles away from the coast.

The most common Decapod zoeas were those of *Portunus puber* and *P. depurator* and *Hyas araneus,* and the three species seen to occur all through the spawning period of the year.

A zoea which probably belongs to *Pilumnus hirtellus* was common in the autumn months, and present in less abundance during the spring. There is little doubt that this zoea is a *Pilumnus,* and the fact that only *P. hirtellus* has been recorded from the Irish Sea makes it highly probable that it is the young of that species. Another record of interest is the zoea of a species of *Pinnotheres,* which appeared very scantily in August. During the past autumn it has been taken in comparative abundance by Mr. Riddell in Cardigan Bay from the "James Fletcher," and a description of it will shortly be published. The species to which the zoea belongs is probably *P. veterum*. In the later parts of the year several kinds of "Megalopa" stages were collected. The greater number of these were the young of *Portunus* or *Hyas*, but several are still unidentified, and at present there is no clue to their parents.

The zoeas and young stages of Anomurans are very common indeed. *Galathea* larvae were present all through the spawning months, but the species to which they belong is not certain. There is possibly a difference in the species of *Galathea* larvae which occur at different times of the year, as has been noted below in the case of *Eupagurus*. The genus is exceedingly abundant in many stages.

A curious regularity in the distribution of *Eupagurus* was seen in the material examined, but I am not yet prepared to state that this condition of affairs is the rule. During the spring *E. bernhardus* was exceedingly common in every stage, and in all but one haul *E. prideauxii** was unrepresented; during the autumn *E. prideauxii* was in its turn as common as its companion species had previously been, and *E. bernhardus* was now absent in all but one haul. The nettings taken from the "James Fletcher" in Cardigan Bay in the autumn of last year do not, however, support these results, as, although *E. prideauxii* is exceedingly common, *E. bernhardus* is almost equally so.

The lengthy spawning period of *E. bernhardus*, already referred to in another publication,† is borne out by the occurrence of a 1st zoea stage in Morecambe Bay as early as February of this year. "Glaucothoe"

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* I hope shortly to publish a description of the zoea stages of *E. prideauxii*.

† L.M.B.C. Memoir XXI, Eupagurus.

stages (of which the species is indeterminate) occur during the autumn sparsely. One specimen was found in August which seemed to belong to *Spiropagurus*, but that adult has not yet been recorded from this district. *Porcellana longicornis* (among the specimens described under this name there are probably included some of *P. platycheles*) is very common in the later months.

In the printed lists of plankton records by the L.M.B.C., the greater number of Macruran larvae seem to be entered under the head of "Mysis stage of *Crangon*." As a matter of fact, the zoea and other young stages of *Crangon* and other allied shrimps are by no means abundant in Prof. Herdman's plankton collections, far the most common Macruran being *Pandalus*. This genus is represented by two species, *P. brevirostris* and *P. montagui*, the former of which is much more common than the latter. Mr. Riddell has found in addition *P. bonnieri* in the hauls from Cardigan Bay, but this species does not appear to occur as far north as Port Erin. *P. brevirostris* is present in both spring and autumn hauls, but *P. montagui* was not found except in the early part of the year. *Crangon* sp. occurred fairly commonly in spring and less so in autumn in all its larval stages. *Hippolyte varians* was present in the spring, and at the same time other larvae closely resembling *Hippolyte* were found which I could not identify. *Nephrops norvegicus* was common in what Sars calls the first and last stages during April.

No larvae of *Homarus vulgaris* were found in the zoea stages, but advanced "lobsterlings" (4th stage ?) occurred in August and September.

There are several common zoea and mysis stages of Macrurans, which do not admit of identification at present, occurring at various periods of the year. These have been temporarily distinguished by the letter M and a distinctive numeral in my note-books, and a description or identification of them will appear in due course.

During April, some Euphausid larvae (probably of *Thysanoessa* sp., and perhaps of *Meganyctiphanes* sp.) are exceedingly abundant, both in "Calyopsis" and early "Furcilia" stages in many of the plankton hauls at Port Erin.

REPORT ON SOME MUSSEL BEDS IN LANCASHIRE AND NORTH WALES AS REGARDS THEIR LIABILITY TO SEWAGE CONTAMINATION.

With Charts.

By Jas. Johnstone, B.Sc.

Contents.

INTRODUCTION.

At the November meeting of the Scientific Sub-Committee I was asked to prepare a report on the principal mussel beds in Lancashire and Wales. This I now present with regard to some of these beds only: it has been impossible in the time to make a complete investigation of all the mussel areas, and indeed this report could not have been ready had not Dr. Jenkins, Mr. Scott and I already examined many of these mussel-bearing grounds. In June last we visited the Conishead Priory Scar; in July Mr. Scott and I visited Morecambe and Heysham; in the same month Dr. Jenkins and I inspected the Lune mussel beds; in November I visited the Estuary of the Wyre, where I met Mr. T. R. Bailey, Port Sanitary Inspector of Fleetwood, and saw the mussel beds at that port, and at Wardleys. In November Dr. Jenkins and I again visited Morecambe and saw much of the conditions there. Also, in June, Mr. Scott inspected the Roosebeck mussel bed and took samples, and again in November. On most of these occasions I made bacteriological analyses of mussels and sea-water collected from the beds.

The question of the contamination of the local mussel beds has become an important one again, for these reasons:—(1) The action of the Market Authorities and Health Authorities in certain towns in excluding, or attempting to exclude, mussels from certain localities. In one case, that of Blackburn, this action has been taken in virtue of special powers conferred on the local authority by a local Act of Parliament. In other cases the local authorities have apparently acted on the assumption that sewage-contaminated shell-fish are to be regarded as articles of food unfit for human consumption, an assumption which, in my opinion, would be very difficult to prove. (2) The action of the Fishmongers' Company in causing analyses of the shell-fish from various local sources. (3) The Report of the late Dr. Bulstrode, in which reference is made to all the shell-fish beds in the Lancashire and Western Sea-Fisheries District.

All these mussel beds to which reference is here made have already been investigated—some of them very fully. The question of their contamination, which has, apparently, only recently been before the public health authorities, is one with which the Committee has long been familiar, and which they have vainly attempted to bring before the notice of the Legislature during successive Governments, so that it is necessary to explain here why it is again brought before their notice. Also, I wish to take the opportunity of discussing here the present position of affairs as regards the significance of the contamination of shell-fish by sewage matters: I mean the general scientific question. It is now almost ten years since the late Mr. R. A. Dawson and Professor Herdman appeared before the Royal Commission on Sewage Disposal, and gave evidence with regard to local conditions and the need for legislation. During these ten years this question has continually been before the attention of the Committee, and the responsibilities of the latter have been fully realised. I find, however, from a study of the literature, that these ten years have been almost fruitless of result as regards the activity of the public health authorities of this country. Nothing that matters in the least has been accomplished. Even with regard to the scientific questions involved—questions that really belong to public health science, and not to that of the sea-fisheries—we are now in the same position as we were ten years ago. With the exception of a few brilliant researches carried out by private investigators,* nothing has been done, and almost every question raised in 1903 before the Royal Commission on Sewage Disposal still presses for settlement.

I discuss, first of all, certain of these general questions relative to the contamination of shell-fish, and the methods of investigation employed, and then proceed to the consideration of the various shell-fish beds examined during the last two years.

Bacillus Coli and its Significance.

Why is sewage-contaminated sea or estuarine water to be suspected? Not because the sewage is *in itself* dangerous to the public health, but the sewage-contaminated water contains "coli-like" microbes, which again are only to be suspected because among them may be the true *Bacillus coli communis.* This organism is

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* I refer to the papers by MacConkey and Clemensha.

not, however, one which is pathogenic—at least it has not even been attempted to be shown that it may convey disease *via* sea-water and shell-fish; it is suspect because it *may* come from the human intestine, and there it *may* be accompanied by the pathogenic *Bacillus typhosus*. If we find "coli-like" microbes in shell-fish, then we condemn the latter because these microbes *may* indicate the presence of *B. coli*, and the latter *may*, in its turn, indicate the presence of *B. typhosus*. This indirect connection should be clearly understood.

But the true *B. coli communis* is not restricted to the human intestine. It occurs also in the faecal matter of horses, cattle, pigs, goats and geese (at least). It may also occur in human sputum, in the water draining off cultivated land, in rain water, in dust, even in such substances as crushed oats. Its presence in shell-fish is not therefore a proof that the latter are contaminated with human faecal matter. But we may argue, indeed the "epidemiologist" *has* argued, that *B. coli* is not less to be condemned even if it does proceed from the intestine of the domestic animals. Now the covert assumption made in this argument is that enteric fever may attack these animals, that disease-producing organisms may be voided by them, and that these organisms may transmit enteric disease to man; for the only epidemic disease which is to be considered when we speak about sewage-contaminated shell-fish is enteric fever. These several assumptions cannot be proved to have any basis of fact.

Let us assume, however, that both "coli-like" bacteria and the true *B. coli* have the significance that the public health official attaches to them. We have then to consider what is this organism, or category of organisms. It is quite evident on reading the literature relating to sewage contaminated shell-fish that there is no agreement as to what is to be understood by the organism *B. coli*. It is a biological species, and therefore all that applies to the identification of species of animals and plants in general also applies to this bacillus—at least we must assume this until the bacteriologists prove otherwise. Now the recognition of an animal, a disease-producing worm for instance, a malarial parasite, anything of that kind in short, is a matter of no difficulty for the expert. He can say at a glance (after experience, of course) whether or not the thing he is looking at is his animal. This is not the case, however, with a bacillus, for mere inspection fails to identify it. It must be cultivated in a number of nutrient substances, and the changes taking place in those substances must be observed before the organism can be identified with certainty. This is a laborious process, and no matter how great the experience of the bacteriologist may be, it must always be carried out in each analysis.

The point here is that the public health officials in this country have not agreed upon a series of tests which are sufficient to identify "coli-like" microbes. In the case of animals producing disease in cattle or in man there is agreement among biologists. There is also agreement among chemists as to the series of tests defining a poisonous substance, or a food adulterant. But it is quite evident that no such agreement with regard to the characters of "coli-like" bacteria is to be found in public health practice. Let us see what are the common tests employed. In the following table are the tests which have been suggested, and against them are the names of bacteriologists who have worked at shell-fish contamination. The crosses indicate what tests are regarded by each analyst as sufficient to identify the microbes.

Tests for the recognition of *Bacillus coli* used by the Bacteriologists.	MacConkey '09	English Committee on standardisation of *B. coli.*	McWeeney	American Public Health Committee	Klein	Herdman & Boyce	Savage, '05	Savage, '06	Houston "Typical *B. coli*"	Houston *B. coli*, 100 %	Houston *B. coli*, 96 %	Houston *B. coli*, 90 %	Houston *B. coli*, 77 %
1. Fermentation of bile salt glucose broth	×	×	...	...	×	...	×	×	×	×	×	×	×
2. ,, lactose broth	×	×	×	...	×	...	×	×	×	×	×	×	×
3. ,, dulcit broth	×	...	...	...	...	...	...	...	...	...	...	...	...
4. ,, mannit broth	×	...	...	...	...	...	...	...	...	...	...	...	...
5. ,, litmus milk	...	×	×	×	×	×	×	...	×	...	...	...	...
6. No fermentation of cane sugar broth *	×	O	...	...	...	...	×	...	...	×	...	...	...
7. ,, inulin broth	×	...	...	...	...	...	...	...	...	...	...	...	...
8. ,, adonit broth	×	...	...	...	...	...	...	...	...	...	...	...	...
9. ,, inosit broth	×	...	...	...	...	...	...	...	...	...	...	...	...
10. The Vosges and Proskauer reaction (negative)	×	...	...	...	...	...	...	...	...	...	...	...	...
11. Formation of indole	×	O	×	×	×	...	×	...	×	×	×	×	...
12. Reduction of nitrate	...	O	...	×	...	...	...	...	...	...	...	...	...
13. Formation of 28% acid in litmus whey	×	...	...	...	...	...	...	...	...	...	...	...	...
14. Non-liquefaction of gelatine	×	×	×	×	×	...	×	...	...	...	...	...	...
15. Non-staining by Gram's method	...	×	...	...	...	...	...	...	...	...	...	...	...
16. Motility of the bacillus	×	×	...	×	...	...	×	...	...	...	...	...	...
17. Fluorescence of neutral-red broth	...	O	×	...	×	...	×	...	×	×	×	...	...
18. Gas formation of gelatine	...	...	...	...	×	...	...	...	...	This is Houston's "Quintuple Preferential *B. coli* test" as modified by Buchan.			
19. Growth in phenol media	...	...	...	...	×	...	...	...	...				
20. Produces 50% of CO_2 in glucose fermentation	...	O	...	...	...	...	...	...	...				
21. Produces 18% of CO_2 in glucose fermentation	...	...	...	×	...	...	...	...	...				
22. Yellow-brown growth on a potato†	...	O	...	...	...	...	...	...	...				
23. Abundant growth on KI potato gelatine	...	...	...	...	...	×	...	...	...				
24. Fermentation of glucose gelatine	...	...	...	...	...	×	...	...	...				

* Saccharose may sometimes be fermented, and according to the English Standardisation Committee this variability need not be taken into account.

† The English Committee state that this reaction depends on the potato.

The symbols O indicate that the English Committee consider that the tests opposite them are non-essential.

Now we see at once that there is no agreement as to the series of reactions which are to be regarded as proving the presence of *Bacillus coli.* Some few tests, the fermentation of glucose and lactose (these are really all that everyone agrees upon), are common to all the series, but for the rest their adoption appears to be a matter of the amount of time that may be spent upon the identification.

Generally speaking, public health bacteriologists in this country adopt Houston's "Flaginac" test. The mussel, or other shell-fish, is cut up and (after other operations to which I return later) is inoculated in MacConkey's bile-salt broth. The organisms growing in this liquid are then separated from each other by "plating-out" in gelatine, or some other medium. Colonies of the microbes growing on this medium are then selected for further study. As a rule, the analyst endeavours to select colonies which he regards as those formed by *B. coli*, but this procedure is, as Houston (1904, p. 173) says, "a speculative venture even to the expert." Real *B. coli* colonies may, then, be neglected. After isolation, the organism is identified by growth on a number of media, and it has been shown (Houston, 1904, p. 105) that it "cannot be said with certainty which tests should be employed, and how many of them."

Nowadays, however, most public health bacteriologists probably employ Houston's four tests (1) fermentation of lactose broth, (2) fluorescence in neutral-red broth, (3) formation of indole, (4) fermentation and clotting of milk. This is the series of reactions which Houston employed in his work for the Sewage Commission, but it does not appear that he regards it as always essential for the definition of *B. coli.* Thus "a coli-like microbe, to be considered typical, must react positively to *at least three* out of the four tests employed" (Houston, 1904, p. 236). Thus even the meagre array of proof originally suggested by this bacteriologist appears to be too much in actual public health practice.

This will be seen by considering Houston's "Quintuple Preferential *Bacillus Coli* Test,"* a title which at once suggests some really well-planned method of analysis. Let us suppose we use Houston's four tests to identify a bacillus—if all are positive the identification is made. But it may be that one or more of the tests fail; each of them is then given a preferential value, thus fermentation of glucose = 2, fermentation of lactose = 1, production of indole = $\frac{1}{2}$, production of fluorescence = $\frac{1}{4}$, and a negative result with cane-sugar = $\frac{1}{8}$. The total value of the five tests is therefore $3\frac{7}{8}$, and the more nearly the value of the tests approaches to $3\frac{7}{8}$ "the stronger would be the evidence derived from its presence in favour of recent pollution by matter of excremental origin."

At first sight it sounds quite reasonable, but on looking into the matter it is not difficult to detect the confusion of thought involved in the suggestion. The covert suggestion is that of a comparison with the results of a chemical analysis: a solution of prussic acid is always prussic acid, whether it contains 5 per cent., or 0·5 per cent., or 0·00005 per cent. Let us regard the characters of a microbe then as all of the same order, so to speak, and give each a percentage value; the more of these characters the greater the percentage. Thus we

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* I have been unable to procure a copy of the publication in which this test was described (Minutes of the Metropolitan Water Board for the year 1907).

I therefore describe it as used by Buchan, *Journal of Hygiene*, Vol. X, p. 476, 1910.

obtain an 100 per cent., a 96 per cent., a 90 per cent., and a 77 per cent. "coli-like" microbe! But is there really anything sound in the assumption? Clearly not, for if we regard a bacillus as an organism defined by certain characters, we expect that it will exhibit all those characters. It is true that a species of animal or plant may apparently lose a character (as in Mendelian inheritance), also a character may be variable in magnitude: thus the number of fin rays in the dorsal fin of a plaice may vary, yet the fish is undoubtedly a plaice. But the inability of a bacillus to ferment and clot milk, for instance, is an absolute disappearance of a character, and not a decrease in its magnitude. Besides, the laws of variation and heredity in higher organisms are sufficiently well known to allow us to appraise the modifications of character, but this is certainly not the case with bacteria. Variability in these organisms is only just beginning to be studied, and the results so far attained have not, in the very least, affected public health practice.

Let us remember what is the object of these analyses. It is to detect, in shell-fish, &c., microbes (*B. coli*) which have inhabited the human intestine and have then found their way into a new habitat. We detect these microbes by finding that they produce changes in various chemical substances, and that is all we know about them that is of value in recognising them. We find bacilli, which produce all or some of the chemical changes induced by the human *B. coli*, in many other situations. Now let us assume that a colon bacillus may undergo "loss of attribute" and still remain the same biological species. Why should we say that it is only, say, 77 per cent. a *Bacillus coli*?

The "Quintuple Preferential" method, then, works out in actual practice as follows: All the micro-organisms isolated from shell-fish in the usual methods of analysis (the use of MacConkey's bile-salt broth) ferment glucose, and most of them ferment lactose, while a large proportion form indole, and clot milk, and fluoresce neutral-red. Suppose that the colony we isolate from the primary culture is of value 100, then all the bacilli found were *B. coli.* Suppose it has the value 90 per cent., then 90 per cent. were *B. coli*, and so on. *By using this method we are always sure of getting some B. coli as the result of the primary cultures.*

"Bacteriologists," says Dr. Houston in a passage of great literary merit, "ever pressing forward to the unattainable goal of absolute knowledge, are apt to leave in their wake a track of nebulous knowledge which to the uninstructed observer may suggest superficial, and not, as ought to be the case, merely incomplete knowledge." This is really an excess of humility when we remember that it is just this incomplete or superficial knowledge (for both categories of knowledge are identical) that is applied by those who have to do with the public health and the livelihood of fishermen and others.

METHODS OF ANALYSIS.

The method almost universally applied now is that devised by Dr. Houston. Ten oysters (or mussels) are taken from their shells and cut up into small pieces, and put into a vessel of water containing 1,000 cubic centimetres. Various volumes of this liquid are then taken: 100 c.c. is equal to 1 oyster, 10 c.c. to 1/10th oyster, and 1 c.c. to 1/100th oyster. We then take 10 c.c. of the liquid and mix it with 90 c.c. of sterile water, 1 c.c. of this diluted liquid now contains 1/1000th oyster; repeating the same dilution from the last mixture, we get another one in which 1 c.c. contains 1/10,000th oyster, and so on. Somewhere we obtain a dilution where there are no bacilli, at least we find none. We then say that (for instance) 1/1000th oyster contains *B. coli*, but 1/10,000th contains none. *If we only make one such trial* this conclusion seems quite valid.

But the flask containing the dilution, value 1/1,000th oyster in 1 c.c., contained very few bacilli: theoretically it must contain not more than 10. Suppose it contained 5 organisms, and suppose the volume of liquid in the flask is 100 c.c. If we take 1 c.c., the probability that it contains one bacillus is 1 in 20, the probability that it contains none is 20 to 1. We do not find a positive result then, let us say, and we assume that *B. coli* is absent in 1/10,000th oyster; but the chances may really be 20 to 1 that it is present.

Suppose now that the flask containing the dilution (1/1,000th oyster = 1 c.c.) gives a positive result. But it may be that this flask really contained very few bacilli and that we just happened to get one, in spite of the chances against it. But another trial may prove to be negative. We must then state our conclusions in this manner: *B. coli* was present in 1/1,000th oyster, but it may have been absent; or it was absent in 1/1,000th oyster, but it may have been present. All that we must say is that *B. coli* was present in 1/100th oyster and absent in 1/10,000th oyster, for the statistical error clearly involves three dilutions. If we wish to be more precise we must make a number of cultures from each flask and then calculate the probabilities.*

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* All this is obvious enough and similar, or analogous, precautions against error would be taken in chemical or biological research. But I can find nothing in bacteriological literature to show that these considerations affect public health bacteriological practice.

Or we must adopt a better method of analysis. Clearly, if we only cut up a mussel or oyster into small pieces, some of the bacilli present in the animal's body may adhere to the pieces. We must, in order that the method may be reasonably accurate, grind up the pieces of oyster along with the water in a mortar, so as to make a real emulsion. After practising this I am now convinced that the grinding up must be done with sand, so as really to break down the tissues of the shell-fish. We need not fear grinding up and destroying the bacilli.

In nearly all the analyses mentioned in this paper five mussels were taken. The soft bodies of the animals were detached by cutting through the muscles attached to the shell, and left in one of the valves. The flesh was then cut up as finely as possible by means of sharp scissors, and the mass was dropped into a mortar and rubbed down with the pestle. Small Wedgwood mortars must be used; glass ones break on sterilisation. In this way an emulsion of 5 mussels is obtained: it is put into a wide-mouthed flask and water added to make the volume of emulsion 250 c.c. 1 c.c. should then contain 0·02 mussel. Obviously, all the precautions to secure sterility of apparatus and hands are taken. It is quite unnecessary to do more than wash the hands very thoroughly in hot tap water: blank experiments will show this.

Neutral-red, bile-salt, lactose agar has previously been melted, and the tubes are contained in a large dish of water at 45° C. Petri dishes are ready, and 1 c.c. of the emulsion is taken from the flask and put into each Petri dish. The 1 c.c. pipettes should be selected for wide apertures, as the capillary orifices used by chemists may block up. If the drop of fluid remaining after the pipette drains be blown out, a bulb containing sterile cotton-wool must be fitted to the pipette, and this bulb must be blown into, otherwise the breath of the operator *may* infect the Petri dish. The medium is then poured.

Dilutions may be made. If so, it will seldom be found that the mean numbers of colonies in a 1/10th dilution are approximately 1/10th of the higher dilution. It is this that convinces me that exceptional care should be taken in preparing the emulsion.

Five such plates are, as a rule, made, and a mean number of colonies is obtained. Just whether an emulsion of 5 mussels in 250 c.c., or one of 10 in 250 c.c.; or whether a dilution of the 5 in 250 emulsion should be made, ought to be apparent from the natural conditions of the bed from which the sample was collected. Obviously, the analyst himself ought to collect the samples.

The red colonies growing on the plates are then counted, and some of them are isolated in pure subculture. How many should be so isolated will depend on the number on the plate. I think 10 colonies are usually enough. All this is simple, but the identification of the organisms isolated presents formidable difficulties.

The large majority of the large, rapidly-growing colonies on such a plate will give positive results with Houston's "flaginac" series of tests. But if we push the analysis a little further, the investigation becomes much more difficult. In my own experience* only a small proportion of these (about 10 per cent. if the non-fermentation of cane-sugar be regarded as an essential character) are really *Bacillus coli.* One may then find a mean number, per mussel, of "coli-like," or "intestinal" organisms, and then by subculturing and identifying a small number of these, find what proportion

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* See *Journal of Hygiene,* Vol. IX, 1910, p. 430.

of them were *B. coli.* The statistical errors of such an estimation must be reckoned with: obviously, the probable error of the mean count per plate must be calculated, and this may be done by making a trial series of plates, say 10 to 20, and then finding a probable error This is calculated in the following example:—

Ten plates, each inoculated with 1 c.c. of an emulsion of 5 mussels in 250 c.c. of sterile water. The plates contained 210, 258, 274, 277, 302, 305, 352, 375, 453 and 730 colonies. The mean number of colonies is 353.

The frequency distribution is as follows:—

X	f	x'	fx'	$f(x')^2$
Between 200 and 300 colonies...	4	−1	−4	+4
,, 300 and 400 ,,	4	0	0	0
,, 400 and 500 ,,	1	+1	+1	+1
,, 500 and 600 ,,	0	+2	0	0
,, 600 and 700 ,,	0	+3	0	0
,, 700 and 800 ,,	1	+4	+4	+16
	10		+1	21

The mean is $350 + 100 \times \frac{1}{10} = 360$.

The standard deviation is

$$100 \times \sqrt{\frac{21}{10}} = 145;$$

and the probable error of the mean is

$$145 \times 0{\cdot}6745 = 98.$$

This means that we may divide the range of values into two parts: (1) a part lying between the mean −98, and the mean +98, that is, between 252 and 448; and (2) a part between the lower limit of the range and 252, and between the upper limit of the range and 448. Suppose that any single count from a plate is now made, it is just as likely that its value will lie between 252 and 448 as that it will be greater than 210 and less than 252 or greater than 448 and less than 730. It is conventional to regard it as probable that it will lie within the range, mean ± the probable error. That is to say, the mean of our estimation is any number greater than 252 and less than 448, and *in making a comparison of this analysis with a "standard"* we must bear this in mind, for any number within the range is equally probable.

One might possibly use such an estimate for all analyses made by the same methods. Obviously, in comparing the results of two analyses, the probable error of the difference of the averages must be calculated and taken account of. I can find no indications of these statistical precautions in the literature relating to shell-fish bacteriology. One must insist that they are not fanciful precautions, but the application of plain common sense.

These considerations would apply if we were quite certain that we could isolate an organism, call it *Bacillus coli*, and be quite sure that it was an indication of the transmission of organisms, only temporarily* altered in character, from the human intestine to the body of a shell-fish. But there is no convincing evidence that we are able to do this. We do not know how many distinct strains of *B. coli* inhabit the human intestine; nor whether or not there are strains differing so little as to be indistinguishable by the methods in use from those of the human intestine, but with an entirely different

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* Consider the recent work on "pure lines" in heredity. A Bacillus we may *assume* is subject to variability. Let this variability be represented, occasionally anyhow, by small mutations. Then even in the limited time that a bacillus might take to reach a shell-fish from a water-closet, there would probably be time enough for the formation of "pure lines," that is, permanently altered strains of organisms. Let us suppose a bacillus will divide every four hours, in three days there will be 18 generations and 2^{18} individuals. The environment during these three days will have been represented by many different series of conditions.

distribution and significance. It ought to be clearly understood that public health practice, at the present time, does not enable us to state with confidence that any bacillus found in shell-fish or in sea-water or mud can be identified with those living in the human intestine *and nowhere else*, and must therefore have proceeded from the human intestine. Let it be granted that the *B. coli* of the domestic animals is indistinguishable from that of man: then it must be shown that this (bovine, say) bacillus has the same significance as the human one. That is, since enteric fever is practically the only disease which the epidemiologist has to consider in relation to shell-fish, it must be shown that there is bovine enteric, and that it may be communicated *via* pathogenic bacteria, drains, sewers, estuarine water and shell-fish, to man.

An examination of the literature will show that, since the Report of the Sewage Commission in 1904, no serious contribution to the bacteriology of sewage and shell-fish and the normal human intestine—that is to say, no contribution helpful to the fishery administrator or epidemiologist—has been published by the public health researchers, with one or two exceptions. I refer to the papers of MacConkey and Clemensha in the Journal of Hygiene, and to the book—"Bacteriology of Surface Water in the Tropics"—of the latter investigator. In these papers a really adequate attempt to investigate the bacteriology of sewage organisms has been made, but there is no indication that their results have affected public health practice. Indeed the modicum of bacteriological evidence regarded as necessary in 1904 for the identification of *B. coli* is now apparently too great.

The general method of analysis adopted in the reports made to the Lancashire and Western Sea-Fisheries Committee has been, then, to isolate *sewage organisms* from a sample of shell-fish and to estimate the approximate mean number of these contained in a single mollusc. A number of the organisms so isolated are then sub-cultured, and their cultural characters are determined. If, say, one-fifth of these organisms give the reactions of *Bacillus coli*, we may then say that one-fifth of all the sewage organisms isolated in the primary cultures were *B. coli*, paying due attention, of course, to the statistical errors involved. What we do find in such a method of analysis is several categories of organisms. I have given the reactions of 225 such organisms in a former paper (*Journal of Hygiene*, Vol. IX., No. 4, 1910), making use of MacConkey's tables for the identification of intestinal bacteria (*Thompson-Yates Laboratories Reports*, Vol. IV., Part I., 1901; and *Journal of Hygiene*, Vol. VI., 1906), and refer the reader to this paper.

If, however, a report on the liability of a natural shell-fish producing area to sewage pollution consists not only of a bacteriological analysis of the shell-fish themselves and the water in which they are living, but also includes a detailed survey of all the natural conditions —positions of sewer outfalls, direction and strength of tidal streams and currents, wind drifts, rise and fall of tide, &c., and also a critical consideration of the epidemiological evidence available—then it may be possible to dispense with the detailed examination of the colonies of organisms isolated in the primary cultures. If, for instance, a quantity of an emulsion corresponding to one-tenth mussel fails to produce any change in bile-salt glucose broth (see p. 481), we may accept this reaction, without any reserve, as indicating that *B. coli* is so scarce in the shell-fish sampled as to be safely neglected from the point of view of dangerous contamination. If, on the other hand, a quantity of emulsion corresponding to 1/50th part of a mussel contains from 100 to 1,000 organisms* growing on neutral-red, bile-salt, lactose agar, as red colonies, we may be pretty sure that the bacteriological contamination is too great to be neglected; for among these 100 organisms there would certainly be from 10 to 20 which we should be able to identify, on detailed examination, as *B. coli*. Negative results with either of these primary media are of the utmost value; and the investigator will usually be able to find a parallelism between the numbers of "sewage bacteria" isolated and the results of a survey of the natural conditions of the locality from which the shell-fish samples were collected.

It is, nevertheless, quite certain that the identification of the organisms isolated in primary culture is of the highest importance. So long as public health bacteriologists rest content with describing a *B. coli* as an organism fermenting glucose and lactose, forming indole, and fluorescing neutral-red, they must confuse together, not only the various species of intestinal bacteria inhabiting man and the domestic animals, and possibly also sea-birds and fishes, but also perhaps bacteria normally occurring in the soil and in estuarine waters, and perhaps devoid of any significance from the point of view of public health. To class all these forms as "typical" or "atypical" *B. coli* seems to be a quite unwarrantable proceeding. It always was so, on purely theoretical grounds, and it is now plainly erroneous in view of Clemensha's recent work.

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* The lower limit is represented in some of the analyses of River Lune mussels (p. 478). The upper limit may be represented in exceptional cases, or in mussels purchased from fish-shops.

There can be no justification for the wholesale condemnation of a shell-fish area on the results of a bacteriological analysis carried on by Houston's "flaginac" methods, *unless this analysis has been accompanied by a rigorous survey of the area from which the samples were taken, under all possible conditions, and by a critical consideration of the epidemiological evidence available.* Yet, the experience of the Committee is now that several important shell-fish beds have been condemned by public health authorities merely as the result of the bacteriological analyses of samples of mussels obtained from fish-shops or from market stalls. It may be that these analyses were adequate ones, but, so far as I know, the details of the methods employed have not been communicated to the Committee. It is not even certain that the samples in every case were really obtained from the areas implicated. So far as I know, the mere statement of the vendors that they were supplied with mussels from such and such localities is accepted without seeking for further proof. In one such case that has come within my own experience the sample condemned was said to have been obtained from a locality in North Wales. Yet at the time when this sample was analysed the mussel fishery had ceased in the locality in question because of the statutory close season. It might be urged that these mussels were fished illegally during the close season, and while trippers, or casual shell-fish gatherers, may occasionally take mussels from the foreshore at this time, it is clearly impossible (at least it will seem so to those who know the local conditions of the fishery) that mussels should be sent away by railway during this period. In such cases the Local Authority acts, no doubt, in perfect good faith; still, one must demand legal proof of the collection of the sample from a definite fishing ground, if that fishing ground is to be condemned as the result of the analysis.

In the present Report the main evidence considered is that founded on repeated surveys of the shell-fish beds. It might be urged that (as in Dr. Bulstrode's last enquiry) this evidence is, in itself, sufficient. Nevertheless, bacteriological analyses have been made, but it must be pointed out that these are only provisional ones, and that the detailed investigation of the bacteriology of the mussels from local sources is still proceeding, and will be reported upon in due course.

Epidemiological Evidence and Standards of Impurity.

We must be under no illusions as to what is meant by "epidemiological evidence." This is a department of public health work into which the layman is rather diffident about entering—perhaps even the epidemiologist fears to tread there. But, after all, the conclusions are only such as require the balancing of very ordinary evidence; and it is not, apparently, a field only explored by the medical officers of health, since one finds that "trained investigators," or inspectors, are responsible for many of the results.

It is all founded, so far as shell-fish epidemics go, on a very few notable investigations: that made by the late Dr. H. T. Bulstrode, in the cases of the famous enteric explosive outbreaks at the Mayoral banquets at Winchester and Southampton in 1902, for instance; and that made by Dr. Hamer in the case of an enteric outbreak in the East End of London in 1911. It cannot be maintained that either the care with which these outbreaks were investigated, or the success attending the enquiries, have been paralleled in other similar investigations.

I quote a few such instances of epidemiological evidence with regard to the transmission of enteric fever by means of shell-fish. It should be noticed that there is more illness of another kind associated with the consumption of mussels. It more frequently happens that a person eating mussels becomes *suddenly* ill, with all the symptoms of gastro-intestinal poisoning due to ptomäines; or perhaps with symptoms of the peculiar affection called "musselling." These illnesses do not concern us, since they are due to obviously decomposed shell-fish, or to personal idiosyncracy.

Case—ate steamed mussels on 1/9/'07 and frequently from thence to 29/11/'07. Then he ate one mussel raw and remarked to his wife that he would have no more, as they were not good. He took ill on 4/12/'07. His blood gave a + reaction on 27/12/'07. He died on 4/1/'08.

Case—ate cooked mussels on 17/12/'07. He commenced to be ill seven days later. His blood gave a + reaction on 29/12/'07. He died on 3/1/'08. He had influenza prior to 24/11/'07. All the family ate mussels on 17/12/'07, but no other one was ill.

Case—ate raw and cooked mussels several times, beginning December, '07. Others in the house also ate cooked, but not raw, mussels. He became ill on 11-12/12/'07. His blood gave a + reaction on 31/12/'07. He died on 27/1/'08.

Case—ate steamed mussels and oysters at a shop on 21/12/'07, with three companions. He became ill on 3/1/'08. His blood gave a positive reaction on 10/1/'08. He died on 16/1/'08. His three companions remained well.

Case—ate cooked mussels on 21/12/'07, and so did a friend who was with him. He was ill on 28/12/'07.

His blood gave a + reaction. He died on 24/1/'08. His friend did not become ill.

Case—called at shop—and ate 1d. worth of steamed mussels. Her friend ate whelks. Two days later she was ill with stomach pains and diarrhœa. On 3/12/'08 the doctor suspected enteric and the patient was removed to hospital. Her blood gave a – reaction. The case was regarded as enteric.

"The West Cheshire Coroner investigated the circumstances of the death of a boy of seven, Walter Grace, who had died after eating two pocketfuls of mussels gathered off the shore at Seacombe, and also some banana and orange peel out of the gutter. Blame was laid by the Jury on the mussels, the Coroner remarking that that was not the first death in the district from mussels taken in the Mersey Estuary." (One might suggest that the jury contained greengrocers, but not fish salesmen.)

Some cases are, of course, very convincing.

Three men, W., D. and B., called at a shop—at various dates between 2/11/'07 and 20/11/'07, and all ate steamed mussels. B. had been drinking hard. W. became ill on 17/11/'07, D. on 18-21/11/'07, and B. on 22/11/'07. They all had enteric. D.'s wife ate steamed mussels from the same shop on 2/11/'07. She became ill on 13/11/'07. W., B. and D. did not live together, and there was no enteric at the place where they lodged.

These are some of the best of the cases. Many are not nearly so good, and the evidence may reduce down to this—that A. ate mussels at a date antecedent to the onset of illness from enteric fever consistent with the interpretation that the mussels were the cause of disease. Now we must admit that there is some considerable amount of enteric fever which can be traced with reasonable certainty to mussels, or other shell-fish; but it will hardly be possible to accept all the cases in which this cause is alleged—at least not without more evidence than is often adduced. We must reckon with "typhoid carriers," with infected articles other than food, with food-wrapping materials infected in various ways and transmitting the disease, with fly carriers, generally with dirty and unsanitary surroundings. We must always remember the possibility of other articles of food acting as carriers—vegetables, fruits, milk. We must regard personal contact of convalescents with articles of food used by others as a possible cause of distribution. *It is far from being certain that all these causes are excluded in those cases where the infection is "traced" to mussels.* Again, one is perhaps not entirely unjustified in suggesting a not unnatural disposition on the part of Medical Officers of Health and Sanitary Inspectors to push the blame of epidemic disease cropping up in their own areas, on to other areas with which they have nothing to do. Mussels are such a convenient scapegoat. One may urge, in the case of a thickly-populated and dirty part of a big town, that the public health officers should set their own house in order. But no doubt they do their best. One may also urge that the zeal which has been directed to excluding mussels from the public markets, under the Food and Drugs Acts, because they were sewage-contaminated, might also be applied to the destruction of moribund mussels exposed for sale in low-class fish shops; and to seeing that this kind of food is stored in sanitary conditions.

It cannot be urged by the Medical Officers of Health, unless because of inexcusable ignorance, that the Lancashire and Western Sea Fisheries Committee have not done their utmost, with the object of minimising the danger to the public health, to improve the condition of the mussel-bearing areas, and to try and obtain power to deal with this question. I think this activity, and the expense to which this Committee has been put in exercising it, has not been recognised as it ought to have been. It is therefore natural to reply to the public health people with a *tu quoque* in this matter. At any rate, the remarks on "epidemiological" evidence should be borne in mind in considering the conclusions of the last Section of this Report.

STANDARDS.

The same vagueness and "nebulosity" that has been noted in regard to the question of the identification of *B. coli* may be observed also in the utterances of some public health bacteriologists. Houston (1904, p. 107) thus attempts a classification of bacteriological impurities in estuarine waters with respect to shell-fish contamination. He divides such waters into various classes:—

(1) No evidence of objectionable contamination—no *B. coli* in 100 c.c.

(2) Appreciable, though slight evidence—no *B. coli* in 10 c.c., *B. coli* in 100 c.c.

(3) Definite signs of pollution. Suspicious—no *B. coli* in 1 c.c., *B. coli* in 10 c.c.

(4) Obvious signs of pollution. To be condemned—no *B. coli* in 0·1 c.c., *B. coli* in 1 c.c.

Here, then, we have a standard. *B. coli* must not be present in 1/10th c.c.; if so, the water is objectionably polluted. But, this is only bacteriological condemnation, not "necessarily administrative practical or legislative condemnation."

Dr. Houston says that the "provisional bacteriological and topographical conclusions" must be "confirmed by epidemiological and administrative considerations." For instance, "whether the contaminating material is likely to have a high or low enteric morbific value: past epidemiological experience in circumstances broadly parallel, &c." But, again, Dr. Houston tells us that "neither the chemist, nor even the bacteriologist, can place a '*disease-value*' on any given pollution" (1904, p. 103). The "standards," then, do not help us materially. There remains, therefore, epidemiological evidence, but it is clear that this kind of evidence is not always convincing, and further, it is clear that outbreaks of disease would not, in some cases at least, have ever been traced to definite mussel layings *if it had not been previously known that these layings were bacteriologically contaminated.* I would refer in this connection to the case of the Conway Estuary. I can find no suggestion of "epidemiological evidence" in relation to these mussels prior to the publication of my report of 1906, when the Estuary was first shown to be seriously polluted by sewage. Analyses in themselves then do not help us greatly in founding a standard, since we are warned to accept the conclusions of the bacteriologist only *qua* bacteriologist, and not necessarily as anything leading to immediate helpful practical recommendations. It is true that this remark does not apply to the work of the Fishmongers' Company. We find there that all bacteriological results are interpreted into practical administrative ones, that is the mussels are either passed or rejected, as a rule, on the results of the analyses. Nevertheless, little or no information is given as to the precise degree of bacteriological impurity on which these conclusions are founded.

DESCRIPTION OF THE MUSSEL BEDS AND SEWER OUTFALLS.

(1) The Roosebeck, Piel and Conishead Priory Mussel Beds. (Chart I).

These beds have acquired considerable importance during the present season on account of a flourishing fishery on the Roosebeck Scar. This began about the end of September and reached a maximum during November, when 95 tons of mussels were despatched from Piel Station alone. Approximately a similar quantity must have been taken to other centres, such as Baicliff, and sent away from there. The fishery on this bed is a very infrequent one, and except for a few mussels taken occasionally, it is many years since such a quantity of shell-fish have been removed from the Scar.

Chart I shows the position of the bed, with its surroundings. All the cross-hatched area bears shell-fish, but those to the south-west end of the Scar are at present small, though of good quality. In Dr. Bulstrode's Report a considerable area of mussel-bearing ground is shown to extend along the western side of Ulverston Channel, but at the present time there are practically no mussels there. The area fished during November is surrounded by a continuous line: it is, roughly speaking, about half a mile in diameter. During this month it began to dry at about low water of a 14 feet tide (Liverpool tables). It goes down to extreme low water of full spring tides.

There are various other mussel beds in Barrow Channel. There are two small beds, one on each side of the ferry slip at Roa Island, one directly opposite on the beach at Piel Island, and a larger bed further up the channel, at the place locally known as Head Scar. In addition to these, there is a scar at the extreme northern end of Barrow Channel, at the place known as Scarth Hole. This bed is not shown in the chart.

The Conishead Priory mussel bed, which is not shown on the chart, is situated about seven miles to the north of the Roosebeck Scar. A shallow-water channel, Ulverston Channel, extends from Roosebeck right up to Ulverston, and this never dries. It varies in width at low water from about 50 to 70 feet. The Conishead Priory bed is situated on the foreshore locally known as Cope Scar, on the western side of the channel, and about one mile below Ulverston. It is a bed of very little economic importance and is not fished at the present time.

None of the Barrow Channel beds is regularly fished. At very rare times mussels have been taken from the foreshore near Piel, and from the bed in Scarth Hole. Such occasional fishing may occur, during periods of unemployment, by persons who are not fishermen: for instance, during the winter of 1908-9, when there was much unemployment in Barrow. There is always, of course, the possibility of these mussels being taken by trippers, or by local people, for other purposes than marketing. But so far as the public food supply is concerned, the only one of this group of mussel beds that matters is that at Roosebeck, and a proper fishery only occurs here rather infrequently.

The Sewer Outfalls.

All the sewage of Ulverston, representing a population of about 10,000, enters the sea, practically untreated, by an outfall situated at the head of a little creek. This creek opens into Ulverston Channel about a quarter of a mile south of the sewer outfall, and about three-quarters of a mile north from the Conishead Priory mussel bed. Two other small sewers enter the Channel; one (conveying domestic sewage) from Conishead Priory (an hotel), and the other (conveying a manufacturing effluent) comes from a chemical works. All this sewage must flow down the channel during the time of low water, when the volume of water in the channel is least, and must pass directly over the mussel bed on Cope Scar.

The Barrow Channel outfalls are shown in the chart. The principal one is the main Barrow sewer (1 on the chart), a pipe passing out over the sands and discharging at some distance above low water into a shallow gutter, which runs down towards the channel, and an open sewer near this pipe. These sewers carry untreated sewage and serve the populations of Barrow and Dalton—about 72,000 people, at times. The sands in the vicinity of the outfall are very foul, and at certain states of the tide, and with certain winds, the smell of this foreshore saturated with decomposing sewage matter is very obvious. Barrow Channel from the south-east extremity of Walney Island up to Barrow Docks is very narrow at low water of ordinary tides, and all this sewage becomes concentrated there. It is true that even then the sewage must be very greatly diluted, nevertheless we will see that the pollution of the channel water, on the last of the ebb tide, near Roa Island is considerable. In addition to this sewer, a small one (No. 2), serving a population of about 150 people on Roa Island, discharges on the foreshore to the west of the Ferry Slip. There are several small mussel beds near Roa and Piel Islands, and since these come adry at low water of most tides, they must be exposed to very serious risks of pollution.

Three other sewers (Nos. 3, 4 and 5) discharge on the foreshore to the east side of the Piel railway embankment. These serve the population of Rampside (about 150 altogether). They discharge well up the beach.

I do not think that any of these sewers can affect, to a significant extent, the Roosebeck mussel bed. Piel Embankment and Roa Island form a barrier from the mainland down to practically low water in the channel; and there is a training wall, a rubble structure, the top of which is just awash at high water of spring tides, extending from Piel Embankment out to Foulney Island, while beyond Foulney towards the S.S.E. the foreshore is very high and stoney and continues the barrier still further. The ebb tide running out from Barrow Channel runs closely to Piel and Walney Islands, so that the channel just at Walney Point is relatively very deep. The ebbing tide from the more northern part of Morecambe Bay runs down Ulverston Channel to the east of the mussel bed, but unless the tide is greater than a 14 feet (Liverpool) tide the bed does not come adry. It is for the most part, then, covered with water on the ebb tide, so that the sewage reaching it—that from Ulverston (7 miles away) and from Rampside—is enormously diluted. When the bed does come adry the ebb tide water, containing the Ulverston sewage in a state of greatest concentration, then flows down Ulverston Channel to the east of the bed and about half to three-quarters of a mile distant. Now when the tide turns it sets up Barrow Channel on the one hand, and to the east of the mussel bed, over Mort Bank, on the other hand. This flood continues for over half an hour while the tide is still ebbing from the foreshore between the mussel bed and the mainland. When the flood tide does begin to stream over the mussels it will indeed contain a possible admixture of the diluted sewage which had previously ebbed down Barrow Channel. But by this time the sewage must have become so enormously diluted that its effect on the pollution of the shell-fish must have become quite negligible.

We see, then, that the chance of sewage from Barrow Channel, the most important source of contamination, is very remote. On the other hand, the chance of pollution from Ulverston is very remote on account of the distance of the sewer outfall. There remain the three sewers from Rampside: now the volume of sewage discharged from these outfalls is very small, and this liquid, with some land water draining from various "becks," runs down a fairly large and deep gutter not far from the training wall, and some distance from the mussel bed. This empties into the sea to the south-east of Foulney Island.

The consideration of this mussel bed is rather important, not only because it may be the source of an important public food supply, but also because the sources of contamination are such as can easily be reckoned with. We see that it is most unlikely that the shell-fish can be polluted to a significant extent. Yet it is quite certain that bacteriological analysis will indicate *some* degree of contamination, and the only possible conclusion is that this is such as may safely be neglected.

(2) The Morecambe and Heysham Mussel Skears.
(Chart II).

In October, 1906, I reported on the results of some inspections and analyses made by Mr. A. Scott and myself with respect to the Morecambe and Heysham mussel beds; and came to the conclusion that the degree of pollution at that time was not such as need cause alarm, particularly in view of the probability of the improvement of the sewerage scheme of the Borough. Since then, however, Dr. Bulstrode has visited the district in question, and has reported at some length on its condition. Further, there are important changes, both in the sewer outfalls, and in the situations of some of the mussel beds and sand-banks. It is therefore necessary to re-consider the whole question of the liability of these mussels to sewage contamination.

The situations of the main mussel skears and sand-banks are shown on Chart II, but since it was impossible to make a detailed survey the positions of the various beds and banks are only shown approximately. It is hoped, however, that the sketch chart is sufficiently accurate to give a fair idea of the risks of contamination to which these shell-fish are exposed.

The population of Morecambe is, of course, a very variable one. It may be taken as about 11,000 normally, but there is a very considerable influx of visitors during the holiday season, and it is obviously difficult to estimate this. When the sewerage scheme, now in operation, was designed, it was intended to cope with a population of about 60,000 people.

Four sewers now discharge into Morecambe Channel and Ring-hole. One of these (No. 1) conveys treated sewage from the septic tank installation: this discharges into the sea at the point shown, not far from the Skear known as "Seldom Seen." The outfall No. 2 is that referred to in my former report as the "Midland Culvert": it is very much now as it was in 1906. No. 3, the "Queen Street Sewer," has been discontinued. and the sewage formerly discharged by it is now being diverted into the main system. No. 4, the "Calton

Terrace" sewer is also now discontinued, the area formerly served by it being now served by the main system. No. 5 is the "Thornton Road" sewer referred to in my former report, it remains as it was in 1906. No. 6, the "Bare Outfall," is also unchanged. It discharges very near to low water at a position above all the mussel skears. In addition to these sources of pollution the men employed at the ship-breaking works in the Old Harbour must also be reckoned with. About 200 men may be employed at times, and these use closets which discharge directly on the foreshore. There are also two small sewers, serving a population of about 4,000 people at Heysham. The positions of these outfalls are not shown on the chart. They lie between the Morecambe West End Pier and Heysham.

There are also considerable changes in the positions, and in the productivity of the mussel skears themselves. Ring Hole, which in 1906 contained abundance of mussels, and which had been selected for the transplantation of small shell-fish from Heysham Skears, is now sanded up, and there is no suitable ground here for the growth of mussels. The two important skears shown on the 1906 chart, "Seldom Seen" and "Reap" Skears, are now also sanded up. "Baiting Knot" Skear, which lies on the other side of the channel, between the West End Pier and the Old Harbour, still exists. But there are, at the present time, very few mussels on it. The beds known as "Little Skears" are also sanded over, and do not bear mussels in sufficient quantity to count so far as the supply of the markets is concerned. "Jacky John" Skear, that one at the extreme western end of the Heysham series, is also sanded over. All the other beds remain very much as they were in 1906.

Mussel ground exists at "Bare Ayre," that is the shaded part of the foreshore between the Thornton Road and Bare outfalls. There is also good mussel ground at "Stone Skear," which lies towards the other side of the channel, between the Thornton Road outfall and the Central Pier. There are patches of mussel-bearing ground on the rising ground, or brow, between the Central Pier and the Old Harbour, and between the latter and the West End Pier; probably there are smaller patches of mussel ground elsewhere. These latter places, however, are not fished by the regular musselers, and are only exploited by reckless visitors, and sometimes by the unemployed and shiftless elements of the Lancaster population. One or two other smaller mussel beds are not shown on the chart, "Walmsley" deep-water skear, for instance. This is shown in the 1906 chart.

The most important mussel grounds are those on the skears below the main sewer outfall. These skears are: "Old Skear," "Knott-End," "Cockup," "Little-out," "Great-out," and "Bankside." There are channels, or "Gunnells," between some of these skears, and on the bottom of these gunnells mussels may be found. It has been suggested that small mussels, from the higher parts of the skears, might be transplanted into these gunnells, and the suggestion seems to me to be an admirable one.

The position of the principal sandbanks and channels is, as I have said, only indicated roughly on the sketch chart. These banks and channels are not accurately represented in any chart published, and they ought, of course, to be properly surveyed, in the interests of such an enquiry as this. It was, however, quite out of the question that we could attempt this in the limited time at our disposal. It is a suggestion that I commend to the Local Authority or the Scientific Sub-Committee.

One very notable change must be noted. In 1906 the Heysham Skears extended over towards Yeoman Wharf, and Grange Channel was then a comparatively narrow strip of water. But during the last few years extensive changes have taken place in the channels in the upper part of Morecambe Bay between Grange and Morecambe. The result has been that the spit forming the south-west extremity of Lancaster Sands has been eroded away, while material has accumulated on the Morecambe side, encroaching on the channel between Lancaster Sands and the mainland. Yeoman Wharf has also extended much further to the east, so that "Low Skear" has become sanded over. The result of all these changes is that the ebb-tide stream setting down Grange Channel now runs further to the east than it did in 1906, and a much greater volume of water must flow over the Heysham Skears. The dilution of the sewage flowing down from Morecambe towards the Heysham Skears must therefore be greater than it was.

(3) The Fleetwood and Hambleton Beds (Chart III).

The natural conditions here are fairly simple and easily understood. There are three main mussel-bearing areas in the estuary of the river Wyre:—(1) Seaward from Knott-End Ferry, in the channel, and on the sides of the adjacent banks; (2) in the bed of the river itself between the Docks and the Fleetwood salt and ammonia works; and (3) in the bed of the river, and on the foreshore at Hambleton, and extending from about Wardley's Hotel for about three-quarters of a mile seaward. The mussel beds (1) are of no economic importance; those at (2) are often fished, mussels are found on the banks, and also in the bottom of the river on ground which does not come adry. These shell-fish are, as a rule, of rather poor quality. The mussels taken from the river at Hambleton are well-known and fetch a very good price. Those raked from the bed of the river are very fine shell-fish, but those on the foreshore are rather poor in quality.

The Sewer Outfalls.

Formerly all the sewage of Fleetwood, representing a population of about 15,000 people, was discharged into the Wyre between the Ferry and Docks, through various outfalls. At the present time it is diverted from these old outfalls and taken across the Fylde peninsula to a pumping station near Rossall. The outfalls 6 and 7 on the chart are near Rossall Landmark, much further seawards than is shown on the chart, and is thus completely removed from any influence upon the shell-fish beds of the Wyre. There are, however, several other sources of pollution. There are several small drains on the Knott-End side of the Estuary, near to the Ferry, but these need not concern us here. On the Fleetwood side there are two sewers (1) a small drain from an ice factory, and (2) a storm overflow from the main system. Further down the estuary, near the Docks, are three drains conveying manufacturing effluents; (3) comes from a fish-oil works; (4) from a fish-curing house; and (5) from a "fish-meal" works. There are iron pipes terminating well above low water mark, on the beach, so that the effluent reaches the estuary by little brooks flowing right through the mussel beds—at this point, however, the shell-fish are very small and are rarely fished.

The sewage from Hambleton appears to drain into the small becks entering the estuary here. That from Poulton-le-Fylde enters into a little brook called Peg's Pool: this is the outfall marked (8) on the chart.

The manufacturing effluents mentioned above are offensively smelling liquids containing organic matter and sulphuretted hydrogen in solution. I examined these liquids in February, 1911, and reported on the question of the contamination of the Wyre to the Scientific Sub-Committee Meeting of that month. It is, therefore, unnecessary to refer further to them here. Also the question of their discharge is not relevant to this enquiry. They certainly constitute technical "nuisances," and it appears that they may be regarded as detrimental to the mussels in the neighbourhood of their outfalls. The remedy is therefore clear. The discharge can be inhibited either by the Local Authority acting under the Public Health Acts, or by the Fisheries Committee itself in virtue of its bye-laws.

The sewage entering the river at Poulton-le-Fylde is the only serious cause of pollution. This outfall is situated about a mile distant from the Wardley's mussel bed and at low water the diluted sewage must flow down a series of rather narrow channels and then over the shell-fish. Still the volume of water carried up the Estuary on the flood tide is very large, and this must dilute the sewage to an enormous extent. The mussels usually fished are also shell-fish that are raked from the bottom, so that they never come adry.

(4) The Lune Mussel Beds (Chart IV).

In February, 1904, Mr. A. Scott and I visited the Estuary of the Lune and saw the mussel beds there; and I collected samples of the shell-fish and reported on the analyses made. This report was incorporated in a report to the Lancashire County Council by the Medical Officer of Health, and this also contained the results of analyses made by Professor Delépine, of Manchester University.

Dr. Sergeant himself came to the conclusion that he found it difficult to express an opinion as to whether the County Council would be justified in asking the Local Government Board to hold an enquiry (with the object of considering whether the Rivers Pollution Prevention Act should be applied to the case of the Lune). He fully believed, however, that the present system of introducing large volumes of sewage into the river was objectionable and avoidable, and he thought this practice likely to render harmful the shell-fish caught in the estuarine waters. Professor Delépine found clear evidence of the pollution, by faecal matters, of the estuarine water and river banks, and he suggested that these shell-fish might at times become dangerous to health. Mr. Scott and I found distinct naked eye evidence of faecal pollution of the banks of the Estuary in the neighbourhood of Crook Skear; and I found that the mussels from both Crook Skear and Bazil Point Training Wall were polluted, though I then thought that the degree of pollution was not excessive. Ultimately the question of the pollution of the river was submitted to the Local Government Board, but the latter body concluded that there was not enough evidence to justify them in proceeding further with the proposal to declare the tidal waters of the Lune a "stream" within the meaning of the Rivers Pollution Prevention Act of 1876. The whole question then remained in abeyance until early in 1911, when Dr. Bulstrode's report was published. It then became advisable to re-examine the locality and this Dr. Jenkins and I did last July. Finally, the action of the Blackburn Local Health Authority, in excluding Lune mussels from sale within the borough, has brought the condition of the Lune prominently before the notice of the Fisheries Committee.

The Mussel Beds.

The only mussel beds in the Lune are those at the lower extremity between Glasson and Sunderland Point. One of these, situated on the eastern side of the Estuary, is called Crook Skear; the other "bed" really consists of mussels growing on the stones forming the training wall, extending along the western side of the river from Bazil Point to near Sunderland Point. The shell-fish here are of finer quality than on Crook Skear. There are several smaller patches of mussel ground near the training wall, but the shell-fish here are of very little economic importance. South from Crook Skear, and in the bed of the Estuary, there are also mussels, but these never come adry.

The Sewer Outfalls.

The sewer outfalls marked on the chart are those which are referred to in Dr. Sergeant's report to the County Council in 1904. Those lettered A to G discharge mostly domestic sewage, but some manufacturers' effluents are also carried by them. Sewers H_1, H_2, and H_3 discharge the domestic sewage and other effluents produced by Messrs. Williamson's mills. Sewer I carries untreated sewage from the Lancaster Infectious Diseases Hospital. All these serve a population of about 34,000 people. There is no other outfall until Stodday is reached, where a sewer (J), serving a population of about 9,000 people, discharges into the river some distance above low water mark. Two other sewers discharge further down: one (K) at Conder Green opens into a brook which then flows across the sands into the river; the other (L) at Glasson Dock opens into the river directly. The first serves a population of about 1,000 people, the latter about 400 people.

We see, then, that the sources of pollution of the Lune are very numerous. We return later to the question of the effect of all this discharge on the shell-fish beds.

(5) The Mussel Beds in the Estuary of the Conway. (Chart V).

The question of the pollution of the mussels taken from the Estuary of the River Conway is, of course, one which has now passed out of the hands of the Sea-Fisheries Committee. The Corporation of the Borough applied last year (1911) for a Provisional Order under the Sea-Fisheries Act of 1868, which would enable them to improve, maintain and regulate the mussel fishery in a specified area. An enquiry was held at Conway in December, 1911, and in August of 1912 the Act of Parliament (Ch. CXLI., 2 & 3, Geo. V.) confirming this Order received the Royal Assent. The Order enables the Corporation to make regulations, to erect storage and cleansing ponds, and to impose a royalty not exceeding 1s. 6d. per cwt. of mussels. Really the royalty payable by the fishermen is at present fixed at 3d. per bag of mussels exceeding three inches in length, and 2d. per bag of smaller mussels. The object of the Order is to give the Corporation power to arrange that the mussels, which are at present dangerously polluted by sewage bacteria, shall in future be relaid in pure sea water for such a time as will enable the shell-fish to cleanse themselves from the bacteria. Experiments made by Professor Klein, of Bartholomew's Hospital, in London, and by myself in the Estuary of the Conway, have shown that if a grossly polluted mussel be relaid in uninfected sea water for a period of about four days, over 90 per cent. of the contained bacteria become eliminated—

discharged by the shell-fish. This Order seems to me to be an admirable one, and if its provisions are enforced with care and intelligence it should put an end to all trouble with respect to the pollution of the Conway mussels, and should develop to a great extent this important local industry. It is to be hoped that the Corporation will administer it with sympathy and intelligence.

Although the matter has now passed out of the hands of the Fisheries Committee, it is, nevertheless, useful to give an account of the condition of the Estuary of the Conway with respect to the contamination of the shell-fish contained therein. This area has now been investigated since 1904 and the conditions with respect to contamination are probably better known than in any other shell-fish area in the country. Bacteriological investigations have also been made from time to time, and a considerable amount of evidence with respect to the communication of disease by these shell-fish has accumulated. The case of the Conway may thus be regarded as a standard one, with which other similar cases may be compared.

The Mussel Beds.

The cross-hatched areas in the chart represent the positions and extent of the mussel-bearing grounds. These grounds extend from the Harbour at Deganwy to some distance out to sea, altogether outside the Estuary. Most of the bed of the river below low water mark contains mussels, and there is a considerable area of scar-ground, coming adry on low spring tides, which is also covered with mussels. Also there are mussels on the banks at the mouth of the Estuary, on both sides of the channel. Further up the Estuary, from near the town of Conway to some distance above the bridges, there is mussel ground on the channel bottom. Mussels are raked all over the bed of the Estuary on the shaded part, and are picked by hand on the scars.

The Sewer Outfalls.

The sewer outfalls are also marked on the chart and the numbers adjoining them indicate the number of people in the area served by the sewers. Above the bridges there are two sewers, one serving a population of about 600 people, and opening on the western side of the river; and the other serving a population of about 1,250 people at Llandudno Junction, and opening into a little brook which flows down over the sands to open into the Estuary quite close to the tubular railway bridge. On the western side of the river is a further group of three sewers serving a population of about 2,600 people—that of the town of Conway. Further down, two small sewers serve a group of houses (about 690 people) at the place known as Morfa Parade. On the eastern side of the Estuary there are sewers at Deganwy and Tywyn, serving a population of about 1,600. Thus this part of the Estuary, only about 1¼ miles long, and, on the average, about one-third of a mile in width, receives the sewage of a population of about 6,750 persons. Also, above Conway, the sewage from a population of about 4,120 persons also drains into the river.

Bacteriological Analyses.

I give here an account of recent analyses only; many more have been made in the past, but all those to which I refer have been made by identical methods, so that all the results are comparative. I take Conway first, as this locality may be regarded as a standard one, with which the others may be compared.

Conway Estuary.

26 June, 1909.

A sample of mussels taken quite close to Deganwy Sewer outfall.

Five mussels emulsified in sterile water and made up to a volume of 250 c.c.

1 c.c. of the emulsion =
(0·02 mussel) contained 25 intestinal* bacteria (also 55 colourless bacteria).
" " 62 " "
Mean No. of intestinal bacteria per mussel = 2150.

9 August, 1912.

A sample of mussels from the bottom of the river near the north side of the bridge.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of the emulsion =
(0·02 mussel) contained 29 intestinal bacteria (No colourless bacteria).
" " 59 " " " "
" " 33 " " " "
" " 55 " " " "
Mean No. of intestinal bacteria per mussel = 2200.

9 August, 1912.

A sample of mussels from the bight between Morfa Parade and the point of land to the north-west. (Locally, (*Anglice*) "Stinking Pool.")

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 28 intestinal bacteria (1 plate contained about 50 colourless bacteria).
" " 20 " " " "
" " 40 " " " "
" " 18 " " " "
Mean No. of intestinal bacteria per mussel = 1300.

Water Analyses.—The small figures placed in the chart on the Estuary at low water indicate the numbers

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* I call these bacteria isolated in Grünbaum's neutral-red, bile-salt, lactose agar medium "intestinal bacteria" with all the reservations indicated in my general discussion of methods of analysis.

of intestinal bacteria contained in 1 c.c. of surface water. The samples were taken at various times, so that it is inadvisable to calculate a mean. They will, however, give a fair idea of the approximate degree of pollution of the water.

Lune Estuary.

23 June, 1912.

A sample of mussels from the training wall at Bazil Point.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =

(0·02 mussel) contained 53 intestinal bacteria and 1 colourless bacteria.
,, ,, 80 ,, ,, ,, 6 ,, ,,
,, ,, 48 ,, ,, ,, 5 ,, ,,
,, ,, 60 ,, ,, ,, 20 ,, ,,
,, ,, 80 ,, ,, ,, 0 ,, ,,

Mean No. of intestinal bacteria per mussel = 3700.

23 June, 1912.

A sample of mussels from Crook Skear.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =

(0·02 mussel) contained 157 intestinal bacteria and 7 colourless bacteria.
,, ,, 150 ,, ,, ,, 0 ,, ,,
,, ,, 146 ,, ,, ,, 3 ,, ,,
,, ,, 117 ,, ,, ,, 1 ,, ,,
,, ,, 82 ,, ,, ,, 2 ,, ,,

Mean No. of intestinal bacteria per mussel = 6500.

Water Analyses—

1 c.c. of surface water contained—

	At Bazil Point.	At a Pool on Crook Skear.
	77	76
	86	111
	90	120
	88	56
	70	46
Means are intestinal bacteria per c.c.	83	82

Morecambe Mussels.

2 July, 1912.

A sample of mussels from Bare Ayre Point.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 27 intestinal bacteria (2 plates contained colourless bacteria).
,, ,, 96 ,, ,, ,, ,,
,, ,, 95 ,, ,, ,, ,,
,, ,, 53 ,, ,, ,, ,,
,, ,, 39 ,, ,, ,, ,,
Mean No. of intestinal bacteria per mussel = 3100.

3 July, 1912.

A sample of mussels from Little-out Skear.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 17 intestinal bacteria (1 plate contained colourless colonies).
,, ,, 5 ,, ,, ,, ,,
,, ,, 3 ,, ,, ,, ,,
,, ,, 22 ,, ,, ,, ,,
,, ,, 13 ,, ,, ,, ,,
Mean No. of intestinal bacteria per mussel = 600.

23 November, 1912.

A sample of mussels from Stone Skear.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 4 intestinal bacteria (No colourless colonies).
,, ,, 9 ,, ,, ,, ,,
,, ,, 8 ,, ,, ,, ,,
,, ,, 3 ,, ,, ,, ,,
Mean No. of intestinal bacteria per mussel = 300.

Water Analyses—

Numbers of intestinal bacteria in 1 c.c. of water from :—

Bare Ayre Pt. (3 July, 1912), 61, 44, 36, 43, 28. Mean = 42.
Little-out Skear (3 July, 1912), 0, 1, 0, 1, 0. Mean = 0·4.
Bare Ayre Pt. (23 November, 1912), 7, 11. Mean = 9.
Channel, off Central Pier (23 November, 1912), 3, 8. Mean = 5·5.
Channel, off Old Harbour (23 November, 1912), 6, 14. Mean = 10.
Channel, half-way Old Harbour to West End Pier (23 November, 1912), 28, 40. Mean = 34.
Near Main Sewer Outfall (23 November, 1912), 3, 2. Mean = 2·5.
Off Reap Skear (23 November, 1912), 3, 5. Mean = 4.

Estuary of the Wyre.

23 February, 1911.

Sample of mussels from the Estuary near Wyre Dock.

Five mussels emulsified in 250 c.c. sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 2 intestinal bacteria.
,, ,, 1 ,, ,,
,, ,, 1 ,, ,,
Mean No. of intestinal bacteria per mussel = 66.

9 March, 1911.

Sample of mussels taken from near Wardley's.

Five mussels emulsified in 250 c.c. sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 3 intestinal bacteria.
,, ,, 2 ,, ,,
,, ,, 3 ,, ,,
,, ,, 4 ,, ,,
Mean No. of intestinal bacteria per mussel = 125.

5 November, 1912.

Sample of mussels from the Estuary near Wyre Dock.

Five mussels emulsified in 250 c.c. sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 48 intestinal bacteria.
,, ,, 31 ,, ,,
,, ,, 34 ,, ,,
,, ,, 31 ,, ,,
,, ,, 23 ,, ,,
Mean No. of intestinal bacteria per mussel = 1650.

5 November, 1912.

Sample of mussels from the channel near Wardley's.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 7 intestinal bacteria.
,, ,, 16 ,, ,,
,, ,, 20 ,, ,,
,, ,, 9 ,, ,,
,, ,, 10 ,, ,,
Mean No. of intestinal bacteria per mussel = 600.

Water Analyses—

Number of intestinal bacteria per c.c. of surface water from:—

Channel near Wyre Dock (23 February, 1911), 1, 0, 2, 0. Mean = 0·75.
Channel near Wardley's (10 March, 1911), 26, 24, 17, 24, 20. Mean = 22.

Roosebeck and Barrow Channel Mussel Beds.

27 June, 1912.

Sample of mussels from the Scar.

Five mussels emulsified in 250 c.c. of sterile water.

Intestinal bacteria absent in 1/10th mussel.

[NOTE.—In this analysis MacConkey's bile-salt broth was used. All tubes containing 1/10th and lesser fractions of a single mussel were unchanged after 48 hours' incubation. The "enteritidis-reaction" also failed with 1/50th part of a mussel.]

1 November, 1912.

Sample of mussels taken from fisherman's bag immediately after the shell-fish had been taken.

Ten mussels emulsified in 250 c.c. of sterile water.

2 c.c. of emulsion =
(0·08 mussel) contained 33 intestinal bacteria.
” ” 25 ” ”
” ” 21 ” ”
” ” 24 ” ”
” ” 29 ” ”
1 c.c. of emulsion =
(0·04 mussel) contained 15 intestinal bacteria.
” ” 18 ” ”
” ” 8 ” ”
” ” 6 ” ”
” ” 11 ” ”
Mean No. of intestinal bacteria per mussel = 310.

The "enteritidis-reaction" was obtained with 1/12 but not with 1/120th mussel.

No recent analyses of mussels from the Barrow Channel beds have been made. These are hardly necessary since the conditions are such that serious pollution cannot be avoided.

Water Analyses—

A number of samples of water from Barrow Channel, from the end of the Ferry Slip, were made in May, 1908, at various states of the tide. The results are as follows:

Nos. of intestinal bacteria in 2 c.c. of water—

5 hours before high water—Sterile.
3 ,, ,, —1.
1 ,, ,, —0.
6¼ hours before low water—0.
4¼ ,, ,, —0.
2¼ ,, ,, —200.
¼ ,, ,, > 1000.

Conishead Priory Mussel Bed.

13 June, 1912.

Sample of mussels taken direct from the bed.

Five mussels emulsified in 250 c.c. of sterile water.

1 c.c. of emulsion =
(0·02 mussel) contained 6 intestinal bacteria.
,, ,, 11 ,, ,,
,, ,, 21 ,, ,,
,, ,, 24 ,, ,,
Mean No. of intestinal bacteria per mussel = 770.

Summary of results of recent mussel analyses

Locality.	Date.	Mean No. of intestinal bacteria per mussel.
Lune Estuary, Crook Skear	23 June, 1912	6,500
,, Bazil Point	23 June, 1912	3,700
Morecambe, Bare Ayre Point ...	2 July, 1912	3,100
Conway, near Bridges	9 Aug., 1912	2,200
,, near Deganwy	26 June, 1909	2,150
Wyre, near Fleetwood	5 Nov., 1912	1,650
Conway, near Morfa	9 Aug., 1912	1,300
Conishead Priory	13 June, 1912	770
Heysham, "Little-out" Skear ...	3 July, 1912	600
Wyre, at Wardley's	5 Nov., 1912	600
Roosebeck Scar	1 Nov., 1912	310
Morecambe, Stone Skear	23 Nov., 1912	300
Wyre, at Wardley's	9 Mar., 1911	125
Wyre, near Fleetwood	23 Feb., 1911	66
Roosebeck	27 June, 1912	1/10th of a mussel was sterile

Conclusions.

We must now attempt to draw some conclusions of practical value from all this discussion. I take the several mussel beds in the following order:—

1. The Conway Estuary.

It is now unnecessary to attempt to deduce any practical conclusions with regard to this area. But since we know more about it than any of the others, it may be taken as a standard case with which the others may be compared. We have then a narrow strip of water—about ⅓rd of a mile wide and about 1½ miles in length. Few brooks of any size open into this part of the estuary, but the sewage from a population of over 6,000 persons does. The pollution is mostly domestic sewage, as there are few factories in the area discharging other kinds of effluent. It is only land drainage to a slight extent, so that it is reasonable to conclude that whatever pollution is indicated by the mussels is derived from domestic refuse and must contain human faecal matter. It is discharged in the immediate vicinity of the mussels, so that, in the conditions under which the industry is carried on, it is possible for a bagful of mussels to have been bathed in diluted sewage proceeding from houses and water-closets only an hour or so previously, and to reach the consumer a day later.

The recent analytical results are given on p. 301. It is there shown that the number of sewage bacteria contained in the body of one mussel varies from 1,300 to 2,200.

There is abundant epidemiological evidence, showing that enteric fever has been transmitted by these mussels, and even when we examine this evidence as critically as possible, it must still carry considerable weight.

Taking these points into consideration:—

(1) The mussel-bearing area is relatively small, and the volume of sewage entering it is relatively large;
(2) The pollution is recent;
(3) The conditions of the industry;
(4) And the high bacteriological impurity;

we must conclude that the mussels between the Perch, at the mouth of the Estuary, and the upper beds are at present objectionable articles of human food. The mussels from the scars and channel at the mouth of the Estuary, seaward from the Perch, are far less liable to dangerous pollution. But as the industry has been conducted during the last few years it has been practically impossible to distinguish between the mussels from these two parts of the whole area, since all may be washed and stored in the river near to the principal sewers.

2. The Estuary of the Lune.

It is far more difficult to express an opinion with regard to this area. The volume of the Estuary is much greater than that of the Conway, nevertheless it is a relatively narrow strip of tidal water, artificially contracted by training walls, and there is no escape for the sewage: it must mix with the estuarine water. The dilution of the sewage is very great: it is estimated that the volume of water passing up and down the estuary on each tide is about 2,769,000,000 cubic feet, while that of the sewage flowing in during the same period is about 220,000 cubic feet. The dilution is therefore $\frac{1}{12500}$. The flood tide enters the estuary from the open sea and therefore consists of practically unpolluted water.

The Lancaster sewers are about five miles above the Bazil Point mussels. There is a small sewer about half a mile distant, and a fairly large one about 2½ miles distant. The contamination of the mussels is not, then, nearly so immediate as in the case of the Conway beds. At the time of high water, the dilution of the sewage will be as above, but as the tide ebbs this dilution will decrease. At low water the width of the Estuary is represented by the lines indicating the level at low water of ordinary tides, and the volume of water is now very much less, but the sewers still continue to discharge. At low water, Crook Skear dries, but there will still be mussels on the Bazil Point training wall which are bathed by the ebb tide. Now, considering these conditions, it does not appear that the liability of the shell-fish to dangerous contamination will be so great as in the Estuary of the Conway.

On the other hand, the bacteriological results indicate a higher degree of sewage pollution. The recent analysis quoted on p. 478 show 3,700 and 6,500 sewage bacteria per mussel. This is, of course, evident merely from a consideration of the number of sewers and the number of the population served by each.

But again, the epidemiological evidence is not at all strong, in spite of this relatively high degree of bacteriological impurity. Practically the evidence that I know of was summarised by Dr. Bulstrode on p. 225 of his Report (Shell-fish other than Oysters), and it cannot be contended that this is convincing enough to establish a thoroughly good case for condemnation.

We must recognise, however, that the Estuary of the Lune is thoroughly fouled by sewage matters. Naked eye indications of this may easily be seen in the river itself in the vicinity of the outfalls, on the banks as accumulations of putrefying matter in the mud and sand, and even as far down as the sands near Crook Skear. The evidence of the fishermen is that this is affecting the fisheries, not only for salmon, but even for sea-fish, and the agitation for a proper system of sewerage for the town of Lancaster has never ceased since I first visited this Estuary in 1904. I have no doubt that the pollution is now greater than it was in 1904, and must, of course, continue to become greater.

Considering everything, it cannot be concluded that the condition of the Lune mussels is satisfactory, and the proper "administrative practical and legislative" conclusion seems to be this—that these shell-fish cannot be regarded as unobjectionable articles of food.

3. The Morecambe Mussel Beds.

Various questions arise in connection with these beds:—(1) the actual conditions; (2) the bacteriological results; (3) the improvements contemplated, or actually carried out by the local authority; and (4) the local administration.

There are mussel-bearing patches of foreshore and skear ground in fairly close proximity to some of the sewers. Thus there are mussels on the foreshore at Bare Ayre Point, and on the foreshore in front of the town of Morecambe between the piers. When I reported in 1906 there were also mussels on Seldom Seen and Reap Skears, very near to the main sewer outfall, at Baiting Knot, and in Ring Hole itself. At the present time there are no mussels—or at least so few as not to encourage a regular fishery—on Seldom Seen and Reap Skears, in Ring Hole, on Baiting Knot, and on Little Skears. Obviously, mussels in Ring Hole, at Seldom Seen and Reap Skears, and on the foreshore between the piers ought never to be taken for human food, and should these grounds again become set with shell-fish, gathering these ought to be forbidden.

So also the mussels at Bare, on the foreshore, must be subject to risks of pollution too serious to admit of them being regarded as suitable articles of food—at least so long as the present outfalls at Thornton Road and at Bare continue to be used. A glance at the chart is sufficient to establish this conclusion—at least that is my opinion.

The conditions at Stone Skear require more careful consideration. This mussel ground is about half-a-mile from the nearest outfalls—Thornton Road and Bare, but it showed (in November last) far less bacteriological contamination than I expected. Probably the dilution of the sewage discharging from these outfalls is so great that the contamination may be neglected. At any rate, both this ground, and that at Bare Ayre Point, might be regarded as clean, if only these two sewers were joined up to the main system.

I think there can be little doubt that the contamination of the mussels at Heysham Skears may be neglected. These skears are at a distance of from one to two miles from the main sewer outfall, *and they are in the open sea.* The ebb-tide water flowing over them does not come entirely from Morecambe Channel, but, even at low water, a large volume of water coming down from Grange Channel sweeps over the skears and must dilute enormously the already diluted sewage coming down from Seldom Seen Skear. One cannot visit these skears without realising that the danger of sewage contamination is largely imaginary, and that the mussels taken from them are to be regarded as suitable articles of food.

So far as the analyses made during this year go, they confirm this conclusion. The mean number of sewage bacteria isolated from a sample taken from Little-out Skear in July was 600, while the sample of water taken showed, in five plates made, a mean number of 0·4 bacteria per c.c. This, when considered along with the natural conditions, may be regarded as negligible.

But if the sewers still opening into the channel at Morecambe were connected up to the main system, and if the lavatories at the Old Harbour could also be drained into the main sewer, there seems to be no reason why the mussel ground in Ring Hole, and that on the Skears further up the channel, as well as on the foreshore at Bare, should not be regarded as clean. But this conclusion would only follow provided that the discharge from the main sewer outfall were properly regulated. Obviously, if this discharge takes place at the beginning of the flood stream, dilute sewage would be carried up the channel into Ring Hole, and towards Stone Skear, and the Bare foreshore. If, on the other hand, this discharge could be regulated so as to begin as soon as possible after the stream turned, and to continue to near low water, but be stopped some little time before the tide again began to flow, then the danger of contaminating either the mussels in Ring Hole and further to the east, or those at Heysham Skears, would probably be so small as to be negligible. Whether or not this is possible, and whether those in charge of the sewage works could be depended on to regulate the working of the main sewer in a conscientious manner, is a matter for the consideration of the local authority. Obviously, the freedom from contamination of the mussel beds would depend on this.

The efficacy of the septic tank installation must also be considered, though this is perhaps a minor consideration from the point of view of the dangerous contamination of the mussel beds. What we have to consider is not so much the production of a non-putrefiable effluent as an effluent free from intestinal bacteria, and it does not appear that this is likely to be effected by any system of sewage purification at present in use. Still if such system of treatment as is in use at Morecambe succeeds in breaking up solid faecal matter and producing an uniform effluent in which there are no coarse particles of sewage matter, much would be gained, for a more uniform and speedy distribution of the effluent with the diluting sea-water would be effected. On the only two occasions on which I saw this effluent being discharged there was indeed no solid faecal matter visible, but the effluent itself was a dark, turbid liquid. There were some flocks of gulls on the surface of the water, and this may have indicated the presence of solids which I did not see. Dr. Bulstrode, in his last report, refers to the effluent as a "thick black liquid, containing numerous small pieces of paper, and some small faecal masses, and the discoloration of the water thereby was to be seen for considerable distances round the outfall." We have therefore no assurance that this septic tank installation is being worked in the manner that its designers intended. We cannot, of course, assume that it will always be properly worked. This does not matter so much with regard to the outer Heysham mussel skears, but it is a consideration of some importance with regard to the upper mussel grounds.

The conclusion, then, is that the mussels taken from the Heysham Skears are quite suitable articles of human food, and that there is no dangerous contamination; but that until the improvements suggested by Dr. Bulstrode are carried out, it would be as well to regard the mussels from the upper skears—Baiting Knot, Stone Skear, Little Skear, and Bare, as undesirably contaminated.

Suppose these improvements were carried out: let us admit that the working of the purification installation and outfall discharge in the manner indicated above will remove, or minimise, the danger of contaminating the skears. It must be pointed out that even then this report would not constitute a "certificate" or opinion that the mussels were free from dangerous contamination, for obviously the Fisheries Committee, or its Officers, could not guarantee the intelligent and conscientious working of the sewerage plant. It is quite possible that such a plant, worked under the supervision of the engineer who designed it, might be highly satisfactory, and yet, worked by a couple of unskilled labourers, it might be as good as useless. I do not suggest that this is the case, but how could the Committee guarantee that it won't always be the case? Obviously the example of the Conway Provisional Order should be considered by the Morecambe fishermen and Local Authority.

4. The Wyre Mussel Beds.

I see no reason why these mussels should not be regarded as free from significant contamination. The sewers opening into the Estuary are very few, and a very rapid and strong tide rushes up and down it. All the sewage from Fleetwood is now being discharged on the Rossall shore, at such a point that it cannot possibly affect the Estuary itself. There is a storm overflow into the Estuary. Several small drains discharge manufacturing effluents, and there is a sewer near Poulton-le-Fylde. But these, in my opinion, do not constitute serious sources of pollution. If the manufacturing effluents should prove objectionable, the remedy is clear: they can be dealt with under powers already possessed by the Fisheries Committee.

The analyses made by me in 1911 (see p. 480) show clearly that the mussels are not contaminated to a significant extent. Indeed the contamination in the case of the Wyre and Wardley's mussels was less than that found in any other case, with the exception of the Roosebeck mussels in June, 1912. In November of 1912, however, I repeated these analyses and found that the contamination was considerably greater. This can be explained in various ways: either the storm overflow at Fleetwood had been in operation, or the heavy rains of the weeks preceding my visit had washed down matter from the cultivated land on either side of the Estuary. In either case the pollution would be of far less consequence than that proceeding directly from domestic sewage.

So far as I know, there is no epidemiological evidence of the transmission of disease by these mussels. In these circumstances, and considering the natural conditions and sewerage of the district, I have no hesitation in describing the Wyre mussels as clean. This is also the conclusion arrived at by Prof. Klein in 1903 after examining samples of oysters from Sir Charles Petrie's layings and mussels from the Estuary. In both cases "traces of pollution" were detected, but it was pointed out that the completion of the Corporation's new sewer outfall at Rossall Point would, "when completed, remove any danger of pollution." It is true that Professor Klein in 1912, after this outfall *had* been completed, found that the Wyre mussels were unclean, a result which I find difficult to understand.

5. The Roosebeck and Barrow Channel Mussel Beds.

I have already described the natural conditions on and about Roosebeck Scar. It is evident, from a careful consideration of these conditions, that the degree of contamination to which it is exposed may safely be neglected. There is no evidence that shell-fish from this ground have ever been the means of transmitting disease. The analysis made by me on July 27th of this year showed that intestinal bacteria were absent in 1/10th part of a mussel, and this was an average result: it really means that in 1/10th part of each of five mussels taken indiscriminately from all parts of the bed there could be detected no contamination. This result may be accepted without reserve, for a negative reaction in MacConkey's bile-salt broth indicates that no bacteria resembling *B. coli* could be present in the material examined. On November 1, however, a positive result was obtained. In this analysis a mean of 310 "sewage" bacteria per mussel was found. But having regard to the natural conditions indicated above, this result cannot be accepted without qualification. Obviously, it is desirable that the bacteria found in such an analysis should be subjected to much closer scrutiny. The case is one, obviously, for the rigorous investigation of the characters of the organisms, for we cannot believe that they are to be regarded as typical *B. coli*. I hope to make this more detailed investigation later. In the meantime I have no hesitation in describing these mussels as free from dangerous contamination.

Neither can one have any hesitation in saying that mussels from Barrow Channel should, on no account, be used as human food. The conditions here are such as must lead to serious contamination. I have made no recent analyses of these mussels, but none is necessary, as the natural conditions under which they live are such as to provide condemnation.

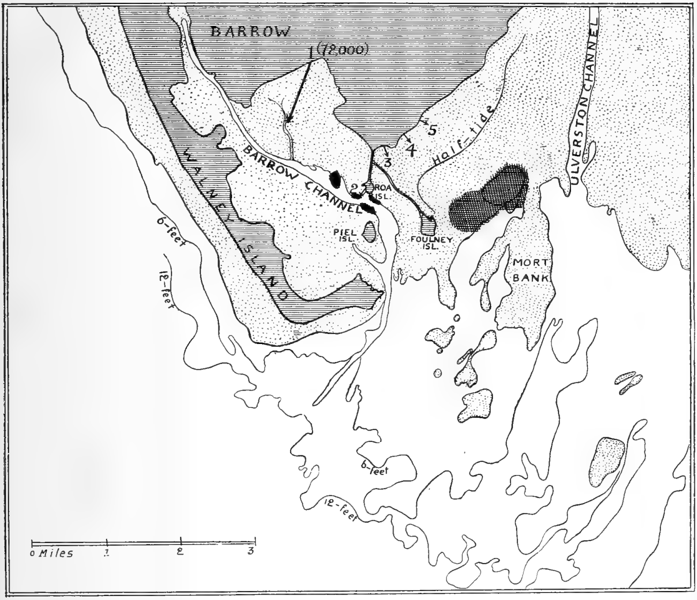
6. The Conishead Priory Bed.

Here, also, we need not hesitate in giving an opinion. The Ulverston sewer threatens this bed so formidably, as Dr. Bulstrode has reported, that it is impossible to describe it as free from dangerous contamination. Or at least one may say that the conditions are such that the bed may at any time become infected; since the sewer outfall is only a short distance away, and the nature of the channel is such that dilute sewage cannot fail to flow over the shell-fish at the time when the depth of water on the scar is least. The bacteriological results (p. 482) do not indicate a high degree of contamination, and, so far as I know, epidemiological evidence is quite absent. Nevertheless, the situations of the sewer and scar are such as to justify us in disregarding these kinds of evidence entirely.

GENERAL CONCLUSIONS.

This Report cannot, of course, be regarded as final. All the inspections and analyses referred to were also made several years ago, but they were no less necessary in 1912, for the conditions in many cases had changed. There can be no doubt that the supervision and investigation of natural, public shell-fish beds ought to be the task of an authority, or officers, dealing with this work alone, and always. It is not only the public health interests that should dictate this policy, but also the practical certainty of the increased development of the shell-fish producing areas, under intelligent control. So far it has been the interest of the public health that has induced the Fisheries Committee to examine this question, with results which are now familiar to its members. The policy of the Public Health Authorities appears to be that of the simple condemnation of the mussels, even of such mussels as those from Roosebeck Scar. It is rather strange that this policy should have been the only reward of the intervention of the Fisheries Committee in aid of the Public Health Authorities; but obviously it is only a phase in the settlement of a problem of great public importance.

CHART I.



WESTERN SIDE OF MORECAMBE BAY, SHOWING THE MUSSEL BEDS AND SEWERS IN BARROW CHANNEL AND AT ROOSEBECK.

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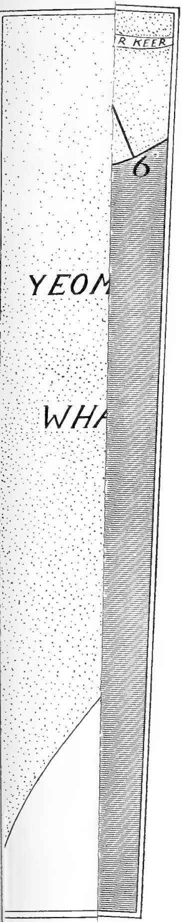

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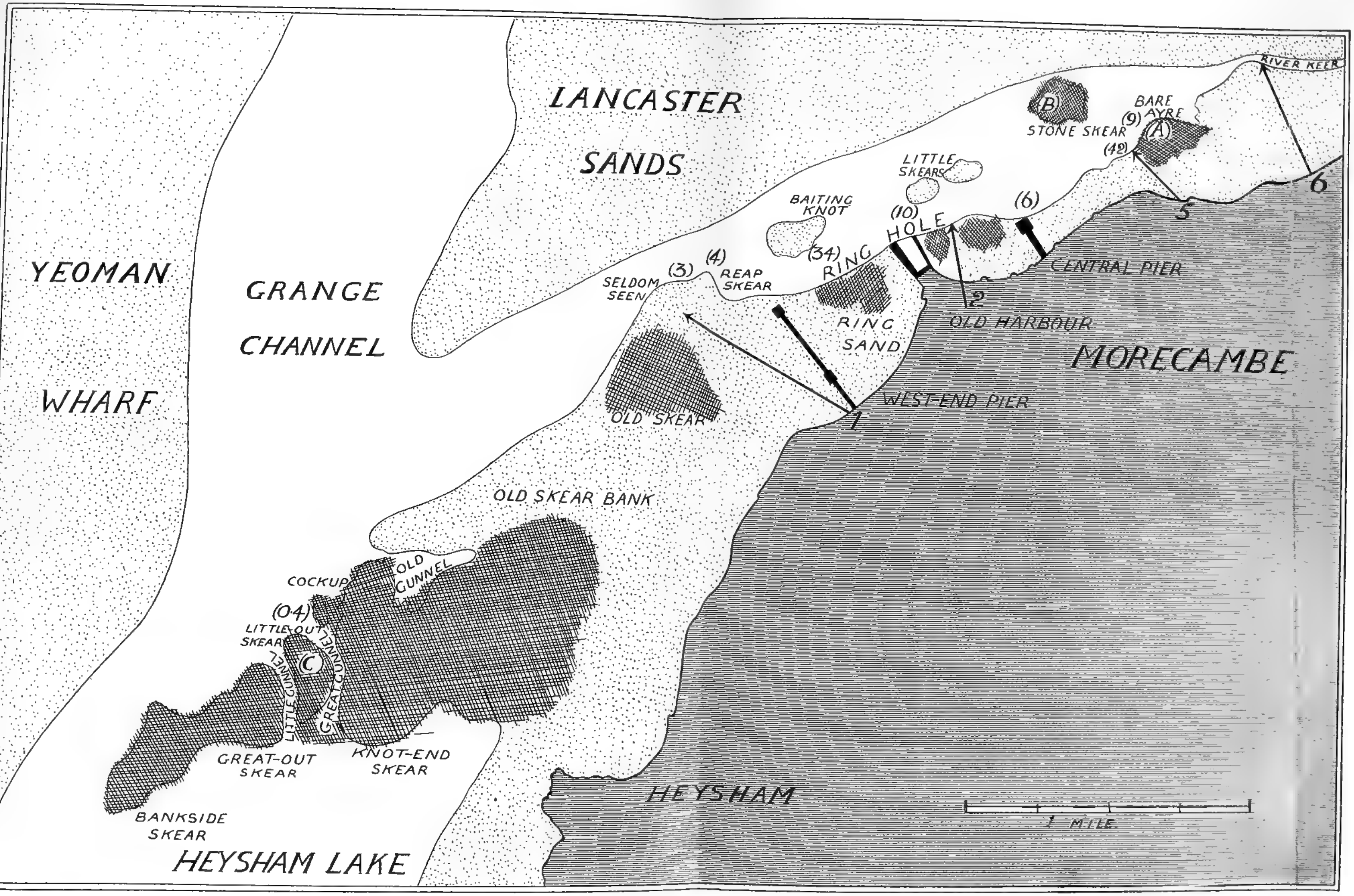
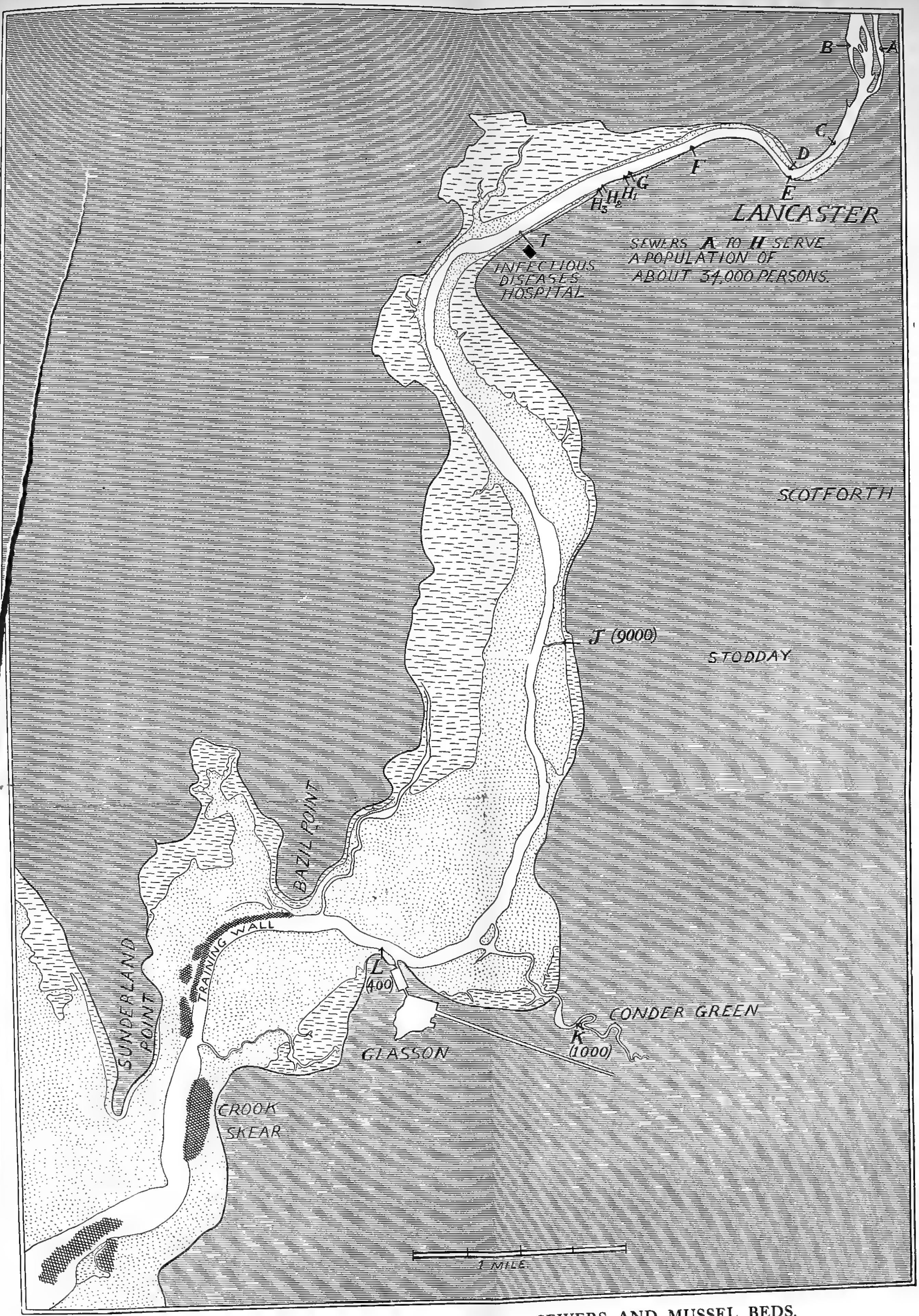
CHART II.



EASTERN SIDE OF MORECAMBE BAY, SHOWING THE SEWERS AND MUSSEL BEDS AT MORECAMBE AND HEYSHAM.

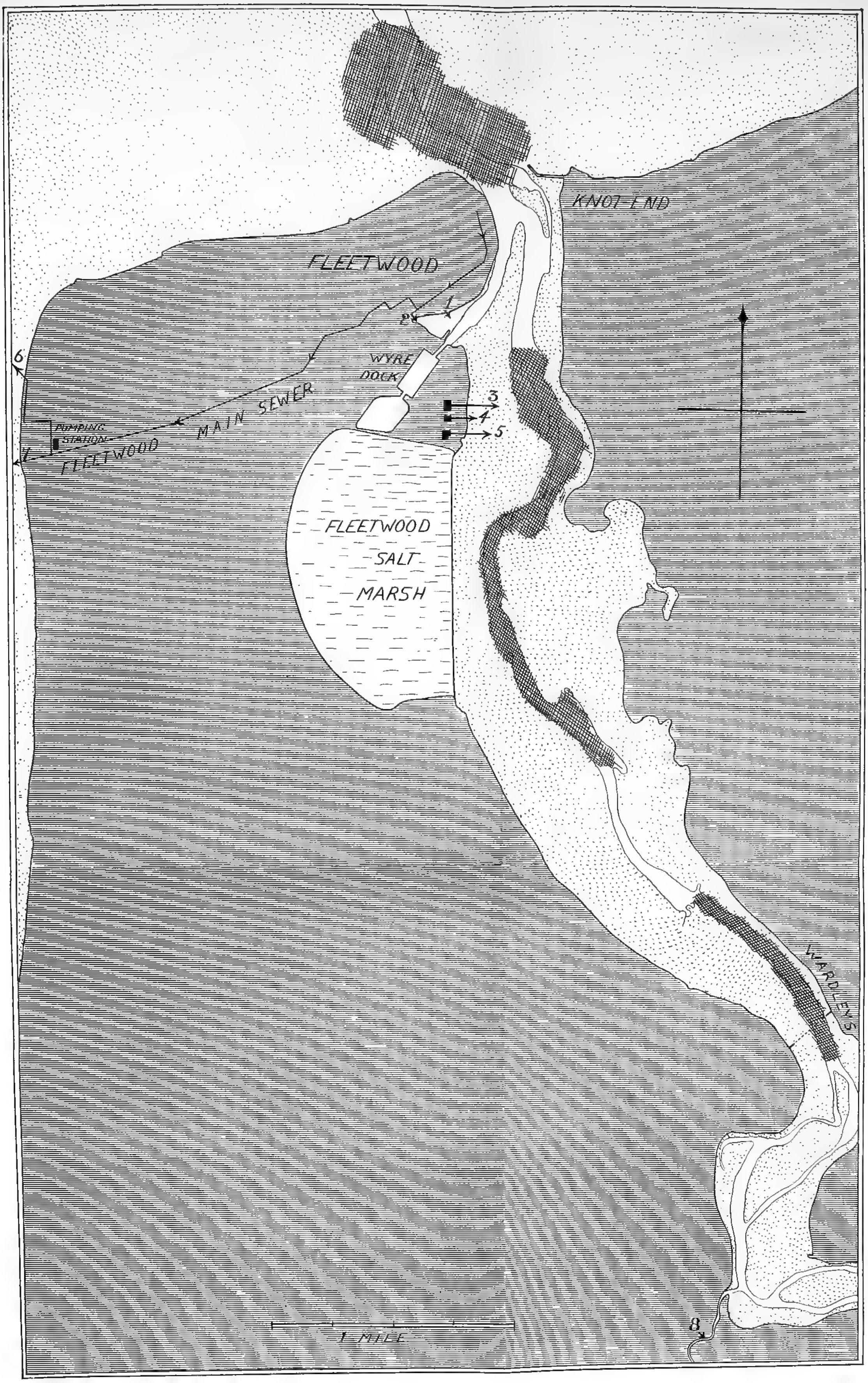
CHART III.



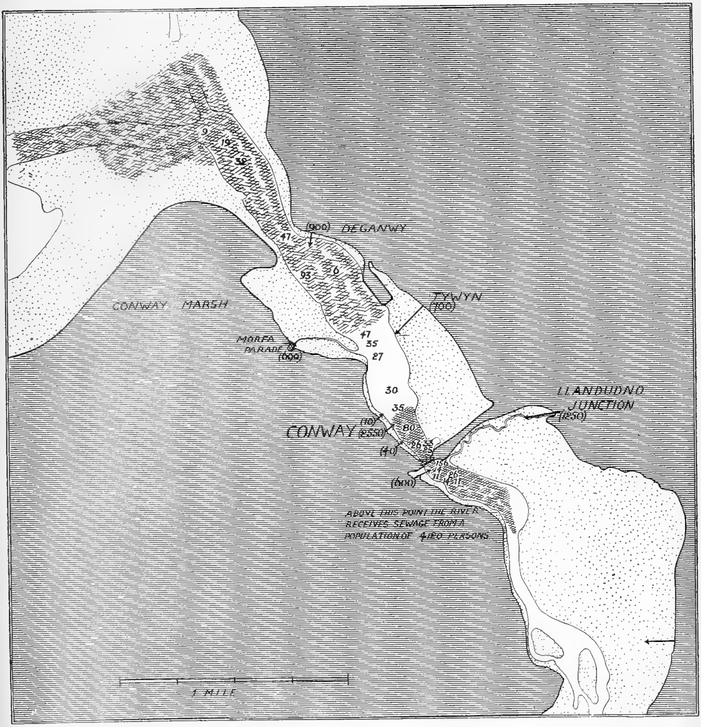
ESTUARY OF THE LUNE, SHOWING THE SEWERS AND MUSSEL BEDS.

V.

CHART IV.



ESTUARY OF THE WYRE, SHOWING THE SEWERS AND MUSSEL BEDS.



ESTUARY OF THE CONWAY, SHOWING THE SEWERS AND MUSSEL BEDS.

L.M.B.C. MEMOIRS.

No. XXI. EUPAGURUS.

BY

H. G. JACKSON, M.Sc.

CONTENTS

CLASSIFICATION AND DISTRIBUTION.

Eupagurus bernhardus (Linn.) is a Crustacean belonging to the sub-class Malacostraca, the series Eumalacostraca, the division Eucarida, and the order Decapoda.*

The Decapoda may be divided into two sub-orders, the Natantia and Reptantia.† The Reptantia contains four tribes, the Palinura, Astacura, Anomura and Brachyura. The Hermit Crabs are included in the super-family Paguridea of the Anomura, and the following is a detailed statement of the families and sub-families of the Paguridea:—

Pylochelidae.—Abdomen macrurous and symmetrical with all the limbs present. Trichobranchiate.

Coenobitidae.—Abdomen more or less unsym-

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* Calman. *Ann. & Mag. Nat. Hist.* Ser. 7, Vol. XIII., 1904.

† Borradaile. ibid., Ser. 7, Vol. XIX., June, 1907.

metrical, some of the limbs lost. Generally phyllobranchiate. Antennal scale reduced. First antenna with very long stalk and flagella ending bluntly. Land forms.

LITHODIDAE.—Abdomen bent under thorax. Body crab-like. Carapace firm all over. Fourth legs like third. Rostrum spiniform. Sixth abdominal appendages lost.

PAGURIDAE.—Abdomen more or less unsymmetrical, some of the limbs lost, generally phyllo-branchiate. Antennal scale well developed. First antenna with stalk of moderate length and flagella ending in a filament. Marine forms.

Sub-family. *Pagurinae.*—Third maxillipedes approximated at base. Chelipedes equal or sub-equal or the left much larger.

Sub-family. *Eupagurinae.*—Third maxillipedes approximated at base. Right chelipede usually, left never, much the larger.

The Eupagurinae contain eighteen genera, two of which, Eupagurus and Anapagurus, are found in British seas. Of the eleven genera which make up the Pagurinae, *Diogenes pugilator* and *Pagurus fasciatus* have been recorded from English waters; the former is never further north than the English Channel, and the latter is of such doubtful authenticity that it may be ignored.

Of the Eupagurinae six undoubted species of Eupagurus and three of Anapagurus are known.

Anapagurus differs principally from Eupagurus in the possession by the male of a genital appendage on the coxa of the fifth left leg. The portion of the carapace in front of the cervical groove is depressed. There are no other differences which can be put on paper, although the genera cannot well be confused. The species of Anapagurus at present recorded from British seas may be thus distinguished.*

ANAPAGURUS—

1. Internal antennae, three to four times the length of the eyestalks, which are short and thick. Ambulatory limbs slightly pubescent.—*A. hyndmanni*.

2. Internal antennae about twice as long as eyestalks, longitudinal orange band on hand. Ambulatory limbs almost smooth; a few small spines on anterior borders. Right chelipede of male enormously developed. Row of small spines on wrist of left chela.—*A. laevis*.

3. Internal antennae about three times the length of eyestalks, which are slender. Chelipedes pubescent. Right hand elongate, ovate and smooth, in length equalling the wrist. Left chela slender with nearly parallel sides. Ambulatory limbs smooth, slightly pubescent.—*A. chirocanthus*, Lilljeborg. (*A. ferrugineus*, Henderson).

The key to the British Eupaguridae given below has for its justification the fact that it enables one to identify the living animal, when means of removing it from its shell are not readily available.

EUPAGURUS—

1. Chelae naked.
    (*a*) Limbs tuberculate and spiny on upper border.
        Strong rostrum.
        Dactyl contorted.
            E. bernhardus.
    (*b*) Limbs granulate.
        Weak rostrum.
        Dactyl straight.
            E. prideauxii.

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* Henderson. *Proc. R. Phys. Soc. Edin.*, vol. IX., 1885-8.

2. Chelae pubescent.
    - (*a*) Left chela median dorsal carina on hand.
        - (i) Three long carinae on right hand.
          Hand ovate.
          Fairly pubescent.
          E. excavatus.
        - (ii) No carinae on right hand.
          R. chela wrist=length hand.
          Very pubescent.
          E. pubescens.
    - (*b*) Left chela without carina.
        - (i) Eyestalk longer than A_2 peduncle and little shorter than A_1 peduncle.
          Chelipedes densely pubescent.
          E. cuanensis.
        - (ii) Eyestalk as long as A_2 peduncle, but shorter than A_1 peduncle.
          R. chela slightly pubescent.
          Wrist spiny on inside.
          E. forbesii.

The genus Eupagurus is of world-wide distribution. *E. bernhardus* is found in Scandinavian and British seas, Bay of Biscay and Mediterranean. There are doubtful records from the Atlantic shores of North America (probably *E. acadianus*), Behring Strait to Kamtschatka. It seems to be vertically distributed from low-water mark to great depths.

The Paguridea are almost unrepresented in geological strata. Ortmann mentions one species, known by its chelae only, in Hungarian Eocene, but he is somewhat sceptical as to its authenticity. Lörenthey (Math. u. Nat. Ber. Ungarn, Bd. 24, 06) has since recorded three species from Oligocene and Miocene. As in the previous case only the chelae have been found.

EXTERNAL CHARACTERS (Pl. I).

In the segmentation of the body the Hermit Crabs exhibit a wider divergence from what might be assumed to be a typical Higher Crustacean condition than any of their allied Decapods. There is no portion of the body from which a segment could be taken which has not lost its primitive design in its specialisation. In the Macrura and Brachyura the simplicity of the abdominal region is preserved, even if the cephalothorax is specialised, but in Eupagurus the condition of the abdomen is such that it is a matter of some difficulty to demonstrate any segmentation at all. An abdominal segment of the Crayfish (*Astacus*) would be found to possess three kinds of protective plates:—The dorsal *tergum*, the ventral *sternum*, and the two lateral *pleura*. An appendage is attached on each side to the outer end of the sternum. The sternum is attached to its fellows in front and behind by means of a flexible arthrodial membrane, and to each flanking pleuron by a hard membrane—the *epimeron*. No such typically developed segment is to be found on the Hermit Crab. The only fully calcified portions of the abdominal region are the first and last segments, and neither of these is in any way normal. The peduncle never at any stage bears limbs and although a narrow sternum is present in the larva, it vanishes altogether in the adult animal, while the sternum and the pleura of the sixth segment are always in a more or less membranous condition.

Cephalothorax.—The exoskeleton of the Decapoda has been described so frequently that it will be unnecessary to do more than refer briefly to points peculiar to the type under consideration. The first character which calls for mention in the cephalothorax is the slight calcification of the fused terga and pleura. The only portion of the dorsal shield which is at all heavily calcified is the "cephalic" region bounded behind and at the sides by very deep grooves (Text-fig 1). The branchiostegite is almost membranous and the cardiac portion of the carapace is only lightly calcified in its anterior portion. On the anterior border there is a median pointed triangular rostrum of small size, and on either side of it, separated by long shallow excavations, are two supra-orbital prominences.* The front now becomes continuous laterally with deep grooves, which pass back to join the cervical groove. The branchiostegite is hinged to the groove on both sides. It drops vertically downwards anteriorly, almost at right angles to the dorsal shield, but the angle becomes gradually less acute further back, till in the thoracic region the lateral walls form a smooth curve with the dorsal side. Were the body not so narrow, the appendages would present an obstacle to the animal retiring into its shell. As it is, they can be folded up beside the body in a very small space. The proximal joints are flattened considerably from side to side to reduce the size of the animal when it is in its shell.

The lateral border of the cephalothorax is prolonged forwards to form a considerable lobe on either side, which projects on a level with the end of the rostrum. This lobe is supported dorsally by its folded and calcified edge.

The hind border of the carapace is reflexed and attached to the eighth thoracic somite, the tergum of which is partially separate. Certain lines and areas are recognisable on the carapace. The most important of these is the groove corresponding to the cervical groove

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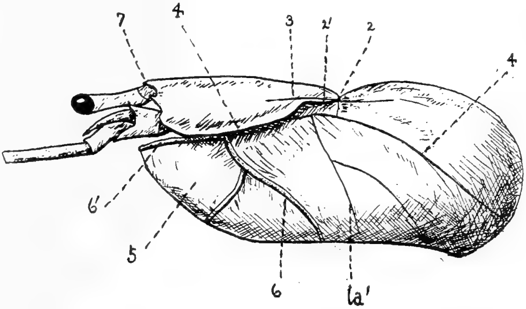
* The front between the supra-orbital lobes in *E. prideauxii* is almost linear.

of other Decapods (Branchial groove, Bouvier). It is very deep and is the more clearly outlined by reason of the comparatively dense calcification of the region in front of it. The homologies of the terms by which writers have described the other grooves and lines of the carapace are not altogether clear, but the following account—principally based on Borradaile—summarises the accounts of the various writers.



Text-Fig. 1.

Anterior to the cervical groove (c. Boas, c. Bouvier, and 2 and 2′ Borradaile) is a deep longitudinal groove extending forwards to the edge of the front. Bouvier calls this the linea anomurica, and Boas calls it line b. This longitudinal groove is continued as a faint crease to the back of the carapace, and this portion Boas calls the linea anomurica. Borradaile combines the naming of the two others, calling the whole line from end to end the linea anomurica. A small crease (*la′*) passing vertically downwards from this line on a level with the cervical groove is also part of the linea anomurica according to Boas. Bouvier and Borradaile do not recognise it. A small longitudinal groove above the linea anomurica and parallel to it starts from the cervical groove and passes forward for a short distance. It is called line d by Boas. It, with its continuation backwards past the cervical groove, is probably homologous with the linea thalassinica (line 3 of Borradaile).

For the Text-figure Borradaile's numbering has been adopted (p. 501).* It is as follows:—

2. Boas' line c.—Bouvier's "branchial groove"—commonly known as the cervical groove.

2′. Continuation of cervical groove at the sides of the carapace.

3. Boas' line d. (front part only), also probably the linea thalassinica.

4. Linea anomurica.

5. Soft area at side of carapace.

6. 6′. Borradaile refers to as "hard plates in this area." In this species calcified bars are present which probably represent similar structures.

7. Rostrum.

The **Sterna** of the cephalo-thoracic region do not require detailed description. Those situated posteriorly are mostly very narrow, that of the fourth thoracic somite being reduced to a mere bar in an antero-posterior direction. This sternal bar is in an interesting condition. It is always displaced slightly to the left—a modification due, no doubt, to the asymmetry of the chelipedes and the greater size of the right limb. All the sterna behind the fifth somite are separated by an arthrodial membrane, and the last two are again reduced to narrow bars—transversely placed—separated by long stretches of membrane. The free articulation of the two last segments on one another aids in conforming the animal to the shape of the shell.

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* Figure of Callianassa (Fig. 125, p. 691), Gardiner's *Fauna of Maldives and Laccadives*, II., 2. *Marine Crustaceans*, Pts. X and XI.

The **Thoracic epimera** form the inner wall of the branchial chamber and support the gills. The whole constitutes a thin, slightly calcified plate, grooved between the segments by vertical sutures. The inturned edges of the epimera at these grooves form part of the endophragmal system.

The **Abdomen** of the Hermit Crab is quite unique among the Malacostraca. It is a distended sac, which might perhaps be described as banana shaped, into which the gonads, digestive glands and renal bladder have been crammed. The first segment (or peduncle) is small and narrow and calcified. The last segment and its appendages is also calcified, but the remaining four segments are represented by an ungainly membranous bag, which shows practically no trace of division into somites. Traces of the terga can be distinguished above each pleopod on the left side, and in a corresponding position on the right (fig. A, Pl. I). They can barely be seen in young specimens and less in males than females. The position of these remnants shows that the fifth segment is greatly and the fourth rather elongated. Mention should be made of the prominent "columellar" muscle on the third segment. It seems to have only a passive function in fitting the body more closely to the shell.

APPENDAGES (Pl. II).

The appendages of *Eupagurus bernhardus* bear very obvious marks of the asymmetry which affects the whole animal. There is always (in the present species) a striking inequality between the chelae, and of the abdominal appendages only one, the uropod, has survived on the left side. The walking legs, head appendages and maxillipedes remain symmetrical.

A considerable degree of specialisation is shown by the limbs. Some are used for facilitating rapid egress and retreat into the shell, some for locomotory purposes, the telson and uropods for hanging on passively to the shell, and the pleopods for causing a flow of water in the shell, and (in the female) for carrying the developing eggs.

The male and female differ only in the disposition and number of the pleopods. The appendages may be arranged as follows:—

Cephalon.	Somite I.	1st Antennae.
	II.	2nd ,,
	III.	Mandibles.
	IV.	1st Maxillae.
	V.	2nd Maxillae.
Thorax.	Somite VI.	1st Maxillipedes.
	VII.	2nd ,,
	VIII.	3rd ,,
	IX.	1st Pereiopods.
	X.	2nd ,,
	XI.	3rd ,,
	XII.	4th ,,
	XIII.	5th ,,

Abdomen.

FEMALE.

	Right.	*Left.*
Somite XIV.	Absent.	Absent.
XV.	,,	1st Pleopod.
XVI.	,,	2nd ,,
XVII.	,,	3rd ,,
XVIII.	,,	4th ,,
XIX.	Uropod.	Uropod.

MALE.

	Right.	*Left.*
Somite XIV.	Absent.	Absent.
XV.	,,	,,
XVI.	,,	1st Pleopod.
XVII.	,,	2nd ,,
XVIII.	,,	3rd ,,
XIX.	Uropod.	Uropod.

The **First Antenna** (fig. 1) is attached almost immediately beneath the eye, but the joints turn inwards and upwards, and thus appear to be attached on the inner side of that organ. The ex- and end-opodite, the former of which is much the larger, bear multiarticulate flagella. That on the exopodite possesses a fringe of long setae. The endopodite is quite small and insignificant. In the proximal joint is lodged the auditory sac, which opens to the exterior by a narrow longitudinal slit on the upper side.

The **Second Antenna** (fig. 2) is larger than the first, and considerably more prominent by reason of the very long flagellum. The protopodite is two-jointed and the flagellum—which represents the endopodite—is attached to it by two moveable segments. A narrow pointed sickle-shaped exopodite, the squame, is present.

The **Mandible** (fig. 3) is a strongly calcified elongate structure. The portion immediately under the mouth is tooth-like and strongly grooved within. Into this groove the head of the palp fits. The palp is a little, jointed structure, probably used for cleaning the biting edge of the mandible and helping the food into the oesophagus. The outside portion of the mandible is a long bar (the apophysis), which serves as an attachment for the powerful muscles moving the appendage.

First Maxilla (fig. 4).—Only the endopodite of this appendage is present, and that is a slight structure, bearing a minute flagellum. The coxa and basis, which almost make up the appendage, are membranous in texture but edged with strong setae.

Second Maxilla (fig. 5).—To this mouth-part is attached the Scaphognathite, which represents a modified exopodite. The endopod is a slender spike, partly hidden by the large basis and coxa, which again constitute the greater part of the appendage. Both are unequally bi-lobed.

The **First Maxillipede** (fig. 6) resembles the Maxillae rather than the two following mouth-parts in its general structure. The coxa and basis are still on the inner side, but neither is divided. The rest of the appendage is thin and membranous. The exopod is minute and bears no flagellum; the endopod is more massive and has a fine setose flagellum. There is no epipodite.

The **Second Maxillipede** (fig. 7).—This, and the following appendage, are more or less typical in structure, possessing a seven-jointed endopod, and a flagellated exopod. The exopod in Mxp. II is comparatively much larger than in Mxp. III.

The **Third Maxillipede** (fig. 8).—The basi-ischiopodite bears a row of powerful teeth, increasing in size proximally. The degree of approximation of the two Maxillipedes affords an important point in classification. These two limbs take an active part in feeding.

The **First Pereiopod** or **Chela** (figs. 9 and 10).—In the present type the inequality in point of size of the Chelae is very striking, the right member being half as long again as its fellow. An exopod is absent, two joints, the ischium and basis, are fused and the propos is prolonged forwards to form with the dactylos the crushing edges.

The **Second** and **Third Pereiopods** (fig. 11) are alike. They are similar in essential structure to the Chela, but they are not chelate and the dactylos is long, curved and grooved. It is characteristic of the present species that this joint is contorted.

The **Fourth Pereiopod** (fig. 12) is remarkable for the possession of a moveable dactylos, which forms a sort of sub-chelate termination to the limb. File-like surfaces of corneous granules are present on the propos and dactylos. The last three segments are bent at right angles to the rest of the limb in this and the following appendage.

The **Fifth Pereiopod** (fig. 13) is similar to the previous limb, except in its termination. The last joint is flattened and provided with a stiff brush of setae and a surface of corneous granules. The crab continually passes this leg inside the branchial cavity with a scrubbing motion.

The **Pleopods** (figs. 14 and 15) are essentially the same in structure in both sexes, consisting of a protopodite bearing two rami. They are present in the male on the left side only of the third, fourth and fifth segments, and in the female on the second segment as well. All the male and the fifth female appendages are slender and the internal rami are minute. The other female pleopods (the ovigerous legs) are comparatively massive, and the branches are sub-equal and bear long setae.

Uropods (fig. 16).—The uropods are the only paired abdominal appendages in the adult, and they are the same in both sexes. The external ramus of the left one is large and sickle-shaped, and the whole appendage is much larger than the right one.

Autotomy takes place as readily as in Crabs, and in the same manner. (See "Cancer," p. 56.)

Endophragmal Skeleton (Pl. III).

The Endophragmal Skeleton (figs. 17 and 18) is a complicated system of calcified plates in the thorax, which serves chiefly as an attachment for muscles, but also as a supporting framework for the viscera. It is formed by the inturning of the edges of the epimera and sternum of each segment. Typically two vertical plates arise from the fore and hind border of every thoracic sternum, and a similar plate projects from both edges of the pleuron at the side. Thus each plate is double, as it is duplicated throughout by the neighbouring segments. The outgrowths from the sterna are known as the endosternites, those from the pleura (or epimeral plates) as the endopleurites. The endophragmal skeleton in *E. bernhardus* is not well developed and differs in many respects from that typical of the Macrura. The endosternites are only fully developed in the fifth and sixth thoracic somites. The endopleurites conform more nearly to those of such a type as the Crayfish. A sternal canal is never present. Median plates caused by the folding of the sterna sagitto-longitudinally are developed on the fifth and sixth thoracic segments.

Preparations of the endophragmal skeleton, from which the form of the individual somites may be studied, can be best made in the following way.

Remove all of the carapace behind the cervical groove, separating it carefully from the underlying epimera. Cut off the abdomen at the peduncle, and each limb a few joints from the proximal end. Clean out the gut and stomach, after cutting a window in the cephalic shield, and such portions of the overlying muscle, etc., as can be scraped away without injuring the skeleton, and boil gently for a short time in a 10 per cent. solution of caustic potash or soda till the skeleton is clean. It may then be washed and transferred to alcohol.

INTEGUMENT.

The structure of the integument of the Hermit Crab does not differ in any respect but degree of calcification from that usually found in the Crabs and Lobsters. Only the chelae and the first two walking legs are comparable with the calcified portions of a Crab in hardness. The rest of the body is covered by a membranous investment with slight deposits of lime in certain places.

The essential structure of the integument is as follows:—*

1. A **chitinous exoskeleton**, which may be shown to consist of four layers.
    - (*a*) The cuticle, a thin, structureless layer.
    - (*b*) The pigmented layer, fine lamellae parallel to the surface, between which the pigment lies.
    - (*c*) The calcified layer makes up the greater part of the hard exoskeleton. It is laminated, but more coarsely than the previous layer.
    - (*d*) A thin, non-calcified layer.
2. The **epidermis,** which secretes or forms the chitinous layer, and is a single layer of columnar cells.
3. A **connective tissue** or **dermis,** in which are imbedded numerous rosette glands, whose ducts pass through the outer layers to the exterior, blood vessels, muscle fibres and scattered cells.

During *ecdysis* the Hermit Crab follows the same method as that of the Macrura, withdrawing the body first, then the limbs, and lastly the abdomen from the cast-off exoskeleton.

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* Vitzou. Récherches sur la structure des téguments. *Arch. de Zool. expér. et gén.*, T. X. (1882), p. 451.

ALIMENTARY CANAL (Pl. III).

As usual in the Arthropoda, three regions of the alimentary canal may be recognised. The fore-gut or stomodaeum—comprising the oesophagus and stomach—which is lined with cuticle; the mid-gut or mesenteron, which is soft-walled and has no chitinous lining; and the hind-gut or proctodaeum—a term synonymous with rectum in this animal—which is also lined with a chitinous cuticle.

Fore-Gut.

The **Mouth** is a laterally ovate aperture lying behind the foot jaws. It is directly covered by the pair of mandibles. In front of the opening—which is directed downwards—is a broad tripartite fleshy lobe, the labrum, and behind it is a smaller lip, the metastoma. The mouth leads directly into the **Oesophagus,** a thick-walled tube whose lumen is greatly constricted by three massive infoldings of the wall (fig. 20). Bright red pigment is always contained in the walls of the oesophagus. Three bunches of stellate glands—two antero-lateral and one posterior—are present at its proximal end, and similar glands are scattered in the lips of the mouth. Each gland is globular, and the somewhat conical cells composing it are radially placed round a small central cavity. From the cavity a narrow duct, which is almost certainly a single cell, leads to the surface. Similar glands occur in large masses in the walls of the rectum. There seems no reason why these glands should have any other function than that of lubricating the walls of the passages in which they are found, in order to facilitate the ingress and expulsion of the food matter. It is difficult to conceive of any appreciable chemical action being exerted by the oesophageal and labial glands on the lumps of food soaked in sea-water which pass up the tube.

The oesophagus terminates on the underside of the **Stomach** (figs. 21 and 19). Its opening is guarded by a pair of calcified flaps densely fringed with setae. The cardiac portion of the stomach (cardiac fore-gut of Pearson) is considerably larger than the pyloric portion. It is a large membranous bag with a flat roof. The ossicles present in this and the hinder part of the stomach do not diverge sufficiently from the typical form in the Decapod Crustacea to justify a detailed description.* The cardiac ossicle is far more slender than is usual, and is bow-shaped; the pterocardiac ossicles are also slender, and articulate with the long curved zygocardiac bars. The pterocardiac ossicle is almost vertical. Viewed from the side, the oesophageal plates are seen to join the post-pectineal ossicle. Infero-lateral cardiac teeth are present. When the stomach is cut open in sagitto-longitudinal section the general structure of the apparatus can best be seen (fig. 19). The lateral teeth are unusually massive and are prolonged backwards into strongly pectinated ridges. The summit of the cardiopyloric valve also bears a ridge of great blunt setae like a comb. A pectineal tooth is present. There are five valves opening into the intestine, a superior median valve excavated ventrally (fairly large in this species), a pair of dorso-lateral valves and a pair of smaller infero-lateral valves, both richly setose. On the roof of the pyloric region is a pair of semi-circular ridges of setae, and between them a median ridge bears a bunch of setae.

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* See Huxley's 'Crayfish,' Pearson's 'Cancer,' Bronn's 'Thierreich,' Bd. V. 2, and many practical text-books.

MID-GUT.

The pyloric valves project into the achitinous **Mesenteron** or **Mid-Gut.** This is by far the largest part of the intestine and measures on the average about 6 cm. in a well-grown specimen. This great stretch of achitinous gut is the more striking when one examines the allied Eupagurids. The American *E. longicarpus* has chitin stretching into the anterior part of the abdomen, and in our own *E. prideauxii* it is found in about the fourth abdominal segment. In the present species the mid-gut does not cease till it joins the rectum in the fifth abdominal segment. At the base of the pyloric ampullae, at the origin of the mid-gut, the two ducts of the digestive gland originate, and immediately behind their point of origin, but on the dorsal surface, arise a pair of *pyloric caeca* (mid-gut caeca of Pearson). The caeca come off close together and run forward on the top of the stomach for a short distance, closely applied to its walls, and then dip down, passing slightly forwards, till they each end in an irregular coil underneath the stomach.

The **Digestive Gland** (or liver) may conveniently be described now. It consists essentially of a pair of axial tubules stretching from their origin under the stomach to a considerable distance into the abdomen, and giving off numerous diverticula (fig. 25). The axial ducts are round and broad in section, and during their passage through the thorax are applied closely to the latero-ventral side of the alimentary canal. The caecal diverticula which arise from this part are few and short, but when the central ducts have passed the peduncle, they separate from the gut and run the remainder of their course on the surface of the flexor muscles of the abdomen. It is from this part of the tubes that the bulky mass of branching diverticula which fill the cavity of the abdomen arises. The gonads are usually imbedded in the liver, and the alimentary canal either passes between the two lobes or through the right portion. The tubules are not packed very closely together, and they therefore retain in section their circular outline. The digestive gland is copiously supplied with blood by the superior abdominal artery and its branches.

The course of the mid-gut is uninterrupted till it joins the rectum. It is a thin-walled smooth tube, without convolutions, through which the faecal matter can be seen. Just before the rectum a long unpaired caecum (*caec.*, fig. 25) arises from its dorsal surface, which passes backwards between the liver tubules to the dorsal surface of the mass, and terminates in a small coil in the third abdominal segment—a little beyond the testis in the male. The caecum seems to be usually longer in the male than in the female. It has been very badly named the "*hind-gut caecum*," seeing that it arises from the achitinous part of the alimentary canal. There is apparently considerable variation in the place of origin of this unpaired caecum among the Eupagurids, though it is always derived from the mid-gut. It appears to form some index to the extent of the chitinous lining of the hind-gut, as it always comes off at the junction of the two parts. M. T. Thompson describes it in *E. longicarpus* as passing from the thorax back into the abdomen—the reverse direction of *E. bernhardus*—and in *E. prideauxii* it arises in the fourth abdominal segment more than half-way up the abdomen, and is comparatively short.

HIND-GUT.

The **Rectum** is from two to three centimetres long in a full-grown animal. It is thick-walled and muscular, and packed with the rosette-shaped glands mentioned above. The walls are considerably folded internally and have a thick chitinous lining. They are richly supplied with blood from the plexus of vessels which covers them.

The **Anus** opens on the under surface of the telson and is surrounded by a sphincter muscle. In the living animal the rectum exhibits vigorous peristaltic movement.

HISTOLOGY OF ALIMENTARY CANAL.

The walls of the oesophagus are formed of very long narrow cells, with a thick base of fibrous connective tissue and an outer layer of muscle fibres. The lumen is lined with cuticle. Mention has already been made of the glands on the oesophageal walls. The cuticular lining is continued through the stomach, and the gastric mill is formed by calcifications in its substance. No other histological feature of the stomach calls for notice.

The lining of the mid-gut is very characteristic. The cells are columnar, with large nuclei and considerable contents of fatty matter. They have a striated border which appears in sections as a dark lining to the cells. The muscle layers at the base are frequently thrown into small plications.

The epithelium of the hind-gut (fig. 22) is more regular than that of the achitinous gut. The nuclei are smaller and there are very scanty cell contents. A thick chitinous layer lines the gut. Behind the basement membrane is a wide layer of muscle bundles and glands which are arranged in very definite clumps. A layer of connective tissue with blood vessels and nerves surrounds the whole. The structure of the paired and abdominal caeca gives no clue to their function. The cells are long and columnar, with small oval nuclei situated near their base. They have a striated border similar to but narrower than that of the mid-gut. The cavity is occluded by the much folded walls.

The histology of the digestive gland differs somewhat from that described by Pearson in Cancer. The so-called "fat cells" are never scattered round the lumen, but bulge out from one point only at a time (fig. 23). It seems doubtful whether the division into "fat" and "ferment" cells can be justified, and whether the fat cells are not to be considered only as ferment cells engaged in excretion. These cells have a very distinctly striated border (fig. 24). Small deeply-staining cells are found between the larger ones. They probably give rise to the ferment cells. The nuclei of the "ferment" cells are to be found two-thirds of the way from the periphery, those of the "fat" cells at their extreme base, nearly all the cell being filled by the huge oil globule.

BLOOD VASCULAR SYSTEM (Pls. III and IV).

With the exception of the portion of the blood system which relates to the abdomen, the course of the blood, both arterial and venous, is that of a normal Decapod Crustacean. As in the crayfish or the crab, the pure blood from the gills passes to the pericardium and is driven by the heart through definite blood-channels to the various parts of the body, whence it returns for aeration by means of irregular sinuses to the gills.

The **Heart** (fig. 28) lies in a space, the pericardium, situated directly under the cardiac part of the carapace. It appears pentagonal in shape from above and rectangular from the side, though not so markedly as in the case of the Macruran and Brachyuran heart owing to the extension of the postero-inferior angle. Viewed from behind, it has a distinct sinistral inclination. The walls are thick and strongly muscular, and the cavity in older specimens is almost filled by the strands of muscle which pass across it. The blood enters the heart by three pairs of ostia provided with flaps opening inwards—one pair placed antero-dorsally, one latero-ventrally, and one postero-laterally. Seven vessels leave the heart, three passing forwards, three downwards, and one backwards.

The heart-beats are regular in any one individual, but there is some variation in different specimens. The contractions are very explosive, and each contraction draws in the anterior end of the heart, stretching the two lateral and median arteries at the same time.

The **Pericardium,** whose walls have the same general outline as the organ they enclose, is a fairly spacious thin-walled cavity extending from the cervical groove anteriorly to the beginning of the eighth thoracic somite posteriorly. It rests ventrally on the mid-gut, and dorsally is applied closely to the carapace. On either side of the posterior part of the pericardium there is a shallow cavity. These possibly represent the "poches pericardiales" of Brachyura. The blood is brought to the pericardium from the gills, and passes through the ostia to the heart.

The various spaces in the body which are filled with blood do not represent a true coelom. They are morphologically a part of the vascular system which has become greatly distended and which has been termed by Lankester a haemocoel.

A portion of the renal organ and the gonadial sacs may possibly represent the true coelom of other animals.

The **Arteries**[*] (figs. 25, 26 and 27) leaving the heart are for the most part easy to trace, but the dissection is greatly facilitated if about a cubic centimetre of strong borax-carmine or methyl-green solution in water be introduced into the heart of the living animal by a hypodermic syringe an hour before it is killed. It is advisable to stupefy it with a weak solution of alcohol before operating, and the hole in the carapace can be conveniently stopped by a drop of hot wax. The stain will be found to have attached itself to some extent to the walls of the vessels, which are thus rendered visible throughout their courses. Three main trunks run forwards from the heart, the median cephalic (or ophthalmic) artery, and the paired lateral (or antennary) arteries (fig. 25, Pl. II).

The *Ophthalmic* artery (*opth. a.*, fig. 25) lies close to the surface; it may be seen through the carapace in injected specimens. Passing over the top of the stomach without giving off any important branches, it plunges down and divides into two vessels, one on either side of the brain, which supply the region of the front of the cephalon. The vessel is dilated into a flask-shaped bulb just in front of the heart.

The *Lateral* arteries (*ant. a.*) arise on either side of the cephalic artery. While the median vessel rises on leaving the heart in order to surmount the stomach, the lateral arteries turn sharply outwards and pursuing a level course on either side supply both that organ and the surrounding tissues with branches. At their anterior extremities the arteries bifurcate and give numerous branches to the excretory organ and muscles which lie laterally in the cephalon.

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[*] For a comparative study of Decapod arterial systems see :—
Bouvier, *Ann. des sci. nat., zool.*, Ser. 7, Vol. XI, 1891, p. 197.

The *Hepatic* arteries (*hep. a.*) are given off from the sides of the heart. They are small and have no longer the important function which is assigned to them in the Macrura and Brachyura, and their part in supplying blood to the liver has been entirely taken over by the superior abdominal vessel. They terminate in small twigs on the gut.

The *Sternal* artery (*d. st. a.* and *st. a.*, figs. 26 and 28) is the largest and most prominent vessel connected with the blood supply. It arises in the median line at the extreme postero-ventral corner of the heart just underneath the superior abdominal vessel, but while the latter follows in the thorax the course of the gut, the former immediately swings to the left and plunges downwards. After passing the intestine, the sternal artery turns forward sharply and runs horizontally from the seventh to the fifth thoracic somites, when it again turns down and pierces the central ganglionic mass between the nerves of the second and third pairs of pereiopods. Under the nerve chain the vessel divides into anterior and posterior branches, running towards the head and tail respectively (fig. 26). This portion of the vessel may be conveniently called the inferior thoracic portion of the sternal artery. The anterior portion of this ventral artery gives branches to the chelae and the mouth parts, and two median branches ascend through the central ganglionic mass to supply the lower part of the stomach, the caeca, and part of the renal organ. After the branches to the first maxillipedes have been given off, the vessel divides, the two branches pass to the front of the oesophagus and anastomose on its walls, without, however, forming a ring. From each side branches to the maxillae and mandibles arise.

The posterior portion of the sternal artery is typical up to a point, in that it gives segmental branches to the remaining thoracic limbs, but in the adult, and in all probability in the larva, it never passes into the abdomen. This artery, in fact, divides in the sixth thoracic somite into right and left branches, which supply the last pair of pereiopods. Small ascending arteries are given off with all the branches to the pereiopods.

The blood supply to the abdomen is entirely carried by the *Superior Abdominal* artery (*s. abd.*), and the vessel has undergone remarkable adaptation for its extra duties. A large trunk leaves the heart just above the sternal artery and passes above the gut—only giving off small branches—as far as the first abdominal segment. Here it divides into two large vessels. One (*seg. a.*) passes directly downwards to the right, turns backwards, and runs on the top of the flexor muscles. It divides in the third segment into sub-muscular and supra-muscular branches. The former follows the course of the nerve cord and terminates near the last ganglion; the latter gives numerous branches to the liver and gonads and finally divides into branches supplying the uropods, telson and rectum. The other vessel (*s. abd.*), veering slightly to the left, continues on the surface of the liver and supplies the gonads and pleopods. In the female we have the interesting condition that each ovary is partly supplied by one vessel and partly by the other (fig. 27); in the male the morphological left testis is supplied by the ventral (right) branch, while the right testis is supplied by the dorsal (left) branch.

M. T. Thompson finds in the young animal that the fourth zoea and the glaucothoë stages have a superior abdominal vessel with segmental branches, but that on the metamorphosis into the adult all these branches are lost except part of the right one in the second segment. A new artery arises from this branch; it assumes the function of an inferior vessel and develops into the prominent ventral division of the superior abdominal artery present in the adult.

This modification may have been due primarily to the animal's assumption of a shell, and secondarily to the fact that nearly all the organs of the body—which in other Decapod Crustacea are supplied by separate thoracic arteries—are to be found in their bulk extended into the abdomen. One may conjecture, in the first place, that the pressure of the shell on the under-surface of the body would constrict a ventral vessel, especially at the peduncle, in such a way as to make its output of blood inefficient. In the second place, a vessel so remotely connected with the heart as the inferior abdominal, under these disadvantageous conditions, would be of little value in maintaining an efficient flow of blood through the large number of slender ramifying vessels required by the abdominal organs. Its place would tend to be filled by one more directly in communication with the means of maintaining the circulation. Thus the superior abdominal artery, whose size and proximity to the heart qualify it for the task of providing a large quantity of blood, has come to monopolise the supply to the abdomen.

Blood Sinuses and Veins.—The whole of the space inside the body walls might be theoretically considered as one large sinus containing impure blood. The presence of the viscera divide this space up into several smaller sinuses, which are, however, all connected with each other.

Above and in front of the stomach there is a distinct blood space—the *Dorsal sinus.* The main sinus with which the outer afferent vessels of the gill lamellae communicate runs ventrally the length of the thorax. This *Sternal sinus* is continuous with the cavity of the abdomen, which constitutes one great *Abdominal sinus.* The sternal sinus does not communicate directly with the gills, but is connected to the *Infra-branchial sinuses* on each side of the body, into which the gill vessels open—by five distinct clefts on either side—the *Branchial sinuses.* Into the infra-branchial sinuses also open the haemal cavities from the thoracic limbs.

The *Afferent Branchial veins,* mentioned above, run from the infra-branchial sinus up the outer side of each gill. The blood is conducted down the inner side of the gill lamellae by the *Efferent Branchial veins* to the five *Branchio-cardiac veins,* which open by three slits on each side into the pericardium.

The **Blood** is a slightly opalescent but almost transparent fluid in which corpuscles float. The presence of haemocyanin gives it a faint bluish colour, which becomes intensified if the blood be left exposed to air. It coagulates under such conditions to a grey-white solid. The setting is effected by clear amoeboid cells which float in the lymph. Several kinds of cells (or amoebocytes) are to be found in the blood, but, according to Cuénot,* they constitute a series of stages in the breaking down of one kind only. The principal amoebocytes are semi-transparent amoeboid cells with large nuclei and finely granular cytoplasm. These cells increase in size and become full of eosinophilous granules. The almost solid body of granules is a prominent object in the blood at this stage, and amoebocytes in this condition are known as eosinophilous amoebocytes. The

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* *Archives de Biologie*, T. XIII, 1895, p. 245.

cell now degenerates and it is eaten by the clear amoebocytes, which exercise a phagocytic function until the granules make their appearance in them. The granules from the degenerating cells appear to be dissolved by the lymph.

RESPIRATORY SYSTEM.

The branchial cavity is a part of the external world bounded on the inner side by the epimera, and above and on the outer side by a lateral flap of the carapace, which is called the branchiostegite. The gills lie on the epimera. The inflected portion of the carapace is in other higher Crustacea strongly calcified, but in the Pagurids it is always membranous and thin. Consequently the gills are far more exposed than is usually the case. Certain calcified bars serve as some support for this membranous flap, which is quite free, so that water can enter the branchial chamber from all sides except the roof. The action of the scaphognathite keeps the water in circulation over the gills.

The branchiae are phyllo-branchiate—that is to say, composed of numerous flat lamellae placed transversely to a central axis. On the inner side of each axis runs the efferent branchial vessel, and on its outer side the afferent branchial vessel. The gills are smaller in front than behind, and they are all pyramidal with their apices pointing upwards.

All the gills are arthrobranchs but one on the twelfth segment, which is a pleurobranch. No podobranchs are present.

The gill formula is the same on both sides, viz. :—

Segments	vi.	vii.	viii.	ix.	x.	xi.	xii.	xiii.
Arthrobranchs	0	0	2	2	2	2	2	2
Pleurobranchs	0	0	0	0	0	0	1	0

In minute structure the gills are seen to be covered by a thin sheath of chitin, beneath which is a single layer of cells, the epidermis. The lamellae consist merely of this epidermal layer with its chitinous investment on both sides, separated by irregular spaces. A distinct vessel—the outer lamellar sinus—runs round the outer edge of each lamella. It is in communication with the cavity of the lamella (the lamellar sinus). The central axis is dumbbell-shaped and besides connective tissue there are two other kinds of cellular structures to be found in it. These are the branchial excretory cells and the branchial glands first described by Allen in *Palaemonetes.** There are two kinds of these latter structures, and Allen's observation as to their different positions in the animal he studied holds good for *E. bernhardus.* The reticulate glands are distinguished by the fact that the cytoplasm of their cells appears as a deeply staining network, the nuclei are spherical and lie near the base, and the ducts and the nuclei belonging to them are very distinct. The protoplasm at the apex of each cell stains deeper with Erlich's haematoxylin and säurefuchsin than the remainder. This type of gland is almost exclusively found round the efferent vessels. The other type of gland is characterised by the absence of the network, the smaller size of the individual cells and the larger relative size and more central position of the nuclei. It is also much more difficult to follow their ducts and distinguish the nucleus of the duct. This type of gland stains very lightly, and is neither so abundant nor so prominent as the reticulate type. It is generally found round the afferent vessels of the gill axis. In general structure these branchial glands are precisely similar to the stellate cells which are present in the

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* *Quart. Journ. M.S.*, Vol. XXXIV., p. 75, 1893.

alimentary canal, in the dermal layer of the body wall, and on the under side of the abdomen. Cuénot states that the branchial glands give a mucoid secretion.*

EXCRETORY SYSTEM (Pl. IV).

The Renal excretory system of the Hermit Crabs has attained a complexity which no other Crustacean exhibits. In addition to the complex arborisations which ramify between the viscera in the cephalo-thorax, there is (in the present species) a large unpaired abdominal sac. All this belongs to the antennary gland (" green gland ") system.

Excretion is also performed by separate cells in various parts of the body—notably those in the gill axis, and an excretory function has been attributed to the " ferment " cells of the digestive gland.

It is not possible to make a dissection of the excretory system without previous treatment of the animal. A spirit specimen rarely shows more than the abdominal vesicle and the antennary gland, and, at best, indistinct traces of the remainder of the system; so it is essential to make a complete study on living material by means of injections.

The substances which are suitable, *par excellence*, for such injections are methyl-green and säurefuchsin in solution in sea-water. A fairly strong solution, the exact strength is immaterial, should be made of the pure substance. One or two c.c. may be introduced into the animal by means of a hypodermic syringe inserted in the arthrodial membrane under the thoracic limbs. The crab may now be returned to its shell and allowed to live for about forty-eight hours, after which it may be killed

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* *Archives de Biologie.* T. XIII., p. 250, 1895.

and dissected. The antennary gland will not take the coloration, but the rest of the system will be distinctly outlined. It will be found that the colour has also appeared in the excretory cells of the gill axis.

In an injected specimen it will be found that there is an antennary gland situated in the front of the cephalon behind the second antenna, which communicates with a diffuse and complex spongy mass in the thorax leading to a thin-walled bladder, the nephrosac, in the abdomen, all of which represents the "bladder" of other Decapod Crustacea (fig. 29).

Except for the abdominal nephrosac and the median ventral thoracic mass, the system is paired.

1. The **Antennary Gland** (*g.g.*) consists of two parts, which communicate with each other, an inner—the end sac ("saccule") which is surrounded by an outer—the labyrinth. The whole is somewhat kidney-shaped and has a lobulated appearance. The connection with the bladder arises from the upper side, above the notch, and the artery supplying the gland passes in a little lower.

The end sac is slightly exposed on the dorsal surface of the antennary gland. Its cavity is broken by blood lacunae and by the extensive ramifications of its walls. Sections show that few prolongations arise from its dorsal side. The walls are irregular, and are often more than one cell thick. The cells are large and squamous, the nucleus is spherical and at the base of the cells, and the protoplasmic contents are light staining and finely granular. The borders of these cells are irregular and protuberant, and oil globules are often present (fig. 32).

The labyrinth is an intermediate duct between the bladder and the end sac, whose cavity has become excessively convoluted by ingrowths from its walls. The epithelium lining this portion is very distinct from that belonging to the end sac. The cells are still squamous but much smaller, so the nuclei appear to be side by side in straight rows. The border of the cells is regular and without the lobed appearance which characterises that of the end sac. The cytoplasm is scanty and striated; it stains more strongly than that of the end sac. The labyrinth communicates by a narrow passage with the rest of the system.

2. The **Anterior Vesicular Mass** (Marchal)* comprises that portion of the system apart from the antennary gland, which lies in the thorax and cephalon.

The opening of the whole to the exterior is connected with this part of the system. The passage commences close to the connection with the antennary gland. It is at first wide, but rapidly becomes narrow, and passes downwards underneath the second antenna, where the external orifice is situated (fig. 30).

The arrangement of the Anterior Vesicular Mass is as follows:—The canal from each gland expands into a mass of ramifying tubules in front of the stomach (epigastric lobe). Although these two masses are close together in the mid-line, they do not communicate with one another. From each epigastric mass (*eg. l.*) a narrow branching canal runs backwards, closely applied to the muscles, to join another mass of arborescent tubules situated on either side of the stomach opposite to the depression between the cardiac and pyloric ossicle of the gastric mill. Branches from these two lateral paragastric masses (*pg. l.*) pass across the stomach in the above-mentioned depression to meet, but not to coalesce, in the mid-line (*sg. l.*).

Underneath the stomach is a median unpaired

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* *Archiv. de zool. expérim. et gén.*, Ser. 2, Vol. X, 1892, p. 57.

portion (*m. v. l.*), which is connected by anterior and posterior branches to the two lateral masses. The remainder of the system comes under Marchal's head:—

3. The **Posterior Vesicular Mass,** which includes the unpaired bladder in the abdomen and its connecting tubes with the two paragastric masses.

The connecting tubes are a pair of branching ducts which run on the top of the alimentary canal side by side till they reach the abdomen, when they unite in a large thin-walled vesicle (*bl.*) of considerable extent—rather the shape of a centrifuge tube—which is about three-quarters the length of the abdomen. It is called the nephrosac. The walls are composed of squamous epithelium with striated cytoplasm at its base and a large spherical nucleus in the centre of each cell (fig. 31). There is a distinct dark border to the cells of the labyrinth and vesicular masses, which is probably due to a striated margin or "Härchensaum." The bladder is tucked between the lobes of the digestive gland—or between the ovaries in the female.

As the excretory system lies wholly in the venous blood sinuses of the body, excretion is probably carried on by direct diffusion through the walls. In sections of the vesicular masses cells may be seen with their inner portions projecting as a clear vesicle into the cavity of the organ. These vacuoles may be shed as small bladders into the lumen, or the entire cells in the end sac are nipped off and pass to the exterior. The excretory fluid is full of such bladders and single cells.

NERVOUS SYSTEM* (Pls. IV and V).

The nervous system of Eupagurus shows little trace of the asymmetry which involves so many other parts of the animal. The variations in position and size which occur in the nerves supplying the opposite sides of the cephalo-thorax are exhibited in any higher Crustacean, but the twist of the abdomen necessarily causes a certain amount of alteration of the abdominal portion of the nerve-cord. There would be no reason to expect any further modification in a system which is not of large bulk, and whose functions are in no way altered by the change in symmetry.

The degree of concentration of the thoracic ganglia is intermediate between that of the Macrura on the one hand, and of the Brachyura on the other. They are not disposed in a diffuse chain as are those of the Crayfish, nor are they indistinguishably fused as in the common Crab, but the concentration is carried to a stage in which the individuality of the ganglia has been lost, while a more general division into regions representing the fusion of two or more ganglia is preserved. Thus the central thoracic ganglion-mass can be differentiated into three (or perhaps four) main portions, which respectively supply the mouth parts and chelae, the first pair of walking legs, the second and third pairs of legs, and the fourth pair.

The nervous system may be conveniently described in three portions: the brain and its connectives, the thoracic ganglion-mass, and the abdominal chain.

The **Brain** or supra-oesophageal ganglion (fig. 37) is situated in the mid-line, under the anterior margin of the cephalo-thoracic shield, behind the eye-stalks and

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* For a comparative study of Decapod nervous systems see :— Bouvier, *Ann. des sci. nat., zool.*, Series 7, Vol. VII, 1889, p. 73.

above the epistoma. It is transversely ovate from above, and a bi-lobed appearance is given to it by a shallow median depression.

The nerves supplying the principal sense organs and the circum-oesophageal connectives with their offshoots arise from the brain, and branches are also given to the surrounding tissues.

Optic nerves (*n. op.*).—A pair of nerves arise in the front of the brain and pass, diverging slightly, into the eye-stalks. Immediately after passing the base of the peduncle the nerve swells to form a small ganglion, from which fibres supplying the eye muscles arise, and ends in another enlargement under the retina.

Oculo-motor nerve (*n. m. o.*).—The muscles of each eye and its adjacent parts are innervated by a much smaller nerve, which pursues a track parallel to and outside of each optic nerve.

The *Antennulary nerves* ($n.\ a._1$) are really four in number, but owing to the fact that the nerve supplying the first antenna and that supplying the otocyst have coalesced on either side, a single pair only is visible. This pair arises from the under surface of the posterior half of the brain. Each nerve is broad and has but a short course, plunging downwards and forwards on leaving the brain into the peduncle of the limb, where it divides into auditory and tactile and muscular branches.

The *Tegumentary nerves* (*n. teg.*) arise on either side of the brain, slightly above and behind those supplying the first Antenna. Each nerve is broad and prominent, and passes outwards and slightly forwards, surrounded by the mass of excretory gland which envelops the hinder part of the brain. It branches frequently and supplies the integument and other tissues in the front of the head.

A pair of *Antennary nerves* (*n. a.*$_2$) originate behind the Tegumentary nerves. These long and slender nerves pass outwards at right angles to the long axis of the body till they turn sharply forwards towards the second Antennae.

The Brain is connected to the remainder of the nervous system by a pair of long connectives—the *Oesophageal Commissures* (*cm.*)—which arise close together at the back of the brain and curve gently outwards round the oesophagus, to approximate again as they approach the thoracic ganglion-mass. On either side of the oesophagus each commissure dilates to form a par-oesophageal ganglion, from which arise four nerves. Both of the two outside branches are small; the anterior one, which is the smaller, innervates the surrounding tissues, and the larger and posterior one supplies the muscles of the mandible.

Stomatogastric system (figs. 39 and 37).—The two inside branches arise together and pass, diverging towards the mid-line in front of the oesophagus where each joins its fellow from the opposite side, to merge into a median unpaired nerve passing vertically up the front of the stomach. Three-quarters of the way up the anterior wall this median stomatogastric nerve enlarges to form the stomatogastric ganglion, from which several small branches to the muscles and walls of the stomach arise. The stomatogastric nerve then mounts the stomach and, directly on attaining its dorsal surface, forms another ganglion, which gives origin to several small nerves, and finally terminates in a bifurcation above the pyloric portion of the stomach.

After leaving the par-oesophageal ganglia, the commissures pass backwards and become attached close together to the front of the ventral thoracic ganglion-mass. A slender transverse nerve—the post-oesophageal connective—joins the two commissures a short distance behind the oesophagus.

The **Thoracic Ganglion-mass** (fig. 37), in which the oesophageal connectives terminate, lies over the sternal artery on the endosternal plates of the third to sixth thoracic somites. Inward projecting processes from the dorsal parts of the endosternites partly bridge over the valley in which it is found. It is composed of three large masses of fused ganglia, which are divided from each other by constrictions; the first and second of these are somewhat rectangular in shape, and the third is pyriform. A shallow semi-circular groove on the third division marks the separation of the ganglia which are the centres for the fourth and fifth pereiopods from those which belong to the first abdominal segment.

The Central Thoracic Nerve-mass is pierced in the mid-line in three places for the passage of arteries. The most posterior of the three is a huge foramen, through which the descending portion of the sternal artery passes; the others are small perforations which are almost indistinguishable in any but specimens injected for the blood system (*asc. a.*).

Seven paired ganglia take part in the formation of the anterior mass, and seven nerves radiate outwards from it on either side. Those supplying the mouth parts usually come off separately, but there is considerable variation in their arrangement. The branches from the first and second Maxillipedes often coalesce before joining the main nerve trunk, and, less frequently, fusion takes place between the nerves supplying the pairs of Maxillae. The thoracic ganglion mass is symmetrical throughout, so only one side need be described.

The First nerve originates close to the oesophageal commissure and is sometimes bound up with it for a short distance. It is quite slender—the seven nerves increase in size in proportion as we go backwards—and passes directly forward to the mandible.

The Second and Third nerves pass directly to the maxillae, and the Fourth, Fifth and Sixth to the maxillipedes.

The Seventh nerve, which is very broad, comes off at the widest part of the anterior lobe and passes slightly forwards to the chela. With this and the succeeding thoracic nerves two small branches arise which pass upwards and innervate the neighbouring tissues.

The central lobe of the thoracic ganglion-mass is the product of the fusion of but a single pair of ganglia, whose nerves supply the second pereiopod. The remainder of the thoracic limbs are innervated by branches arising from the posterior lobe. They all pass backwards and then turn sharply outwards, as they reach the segment for which they are bound. The thoracic nerve mass shades into the abdominal commissures, which—at first bound together—separate themselves as they enter the abdomen.

The **Abdominal Nerve Chain** (fig. 38) is of the familiar ladder type. There are five paired ganglia. Each pair, however, is almost indistinguishably fused, and they are connected by paired commissures. The five paired ganglia are situated in segments two to six, that belonging to the first segment being fused with the thoracic ganglion mass. From each ganglion branches are given off in a somewhat irregular fashion to the muscles, integument, and to the pleopods, and at least one pair of nerves arises from the inter-ganglionic commissures.

The nerve chain lies under the bulky flexor muscles and over a thin layer of integumentary muscles.

On entering the abdomen the chain slews to the left, passing through the "columellar" muscle to the first ganglion (second abdominal ganglion) in the second segment. This is placed well on the left side of the body, and in a lesser degree so is the third segmental ganglion, which is close to the second, and the fourth. From the fourth to the fifth ganglion there is a longer stretch of connective, which once more brings the chain into the mid-line of the body; and there is another long pair of connectives passing from the fifth through the flexor muscles, till they join the sixth ganglion on the dorsal surface of the muscles under the posterior end of the rectum. From this ganglion branches are given to the uropods, the telson and the alimentary canal. There is a ring round the rectum, but it is uncertain whether there is any actual junction between the two nerves.

The histology of the nervous system in the higher Crustacea is a rather difficult specialised study, which the ordinary student of Zoology will probably not attempt. More advanced workers should refer to the detailed account of the histology of the shore crab (Carcinus), given by Bethe in the following papers:—

Arch. f. mikroscop. anat., v. 44, 1895, p. 579.
Ibid. ... ... v. 50, 1897, p. 460.

SENSE ORGANS (Pl. IV).

The sense organs consist of a pair of compound stalked eyes, a pair of otocysts, and a number of sensory setae scattered over the body.

THE EYE* (Figs. 33 and 34).

The optic peduncle, at the end of which the eye is situated, is a two-jointed structure. The basal joint is short and thick, and it bears on its inner side a spearhead shaped "squame"; the distal joint is long and cylindrical, but narrower in the middle than at either end. The two parts are loosely joined by membrane and the outer moves freely on the inner. The cornea takes up all the anterior end of the second joint. It is circular in outline except for a small invasion of the calcified portion of the stalk on its dorsal and inner side.

The eye is compound—that is to say, it is composed of many separate, similar parts or elements, each of which is called an ommatidium.

The cornea is facetted, and each such area is hexagonal in shape. A fine line bisects each facet diagonally from angle to angle. These corneal facets are the outer ends of the ommatidia, which, owing to the convexity of the cornea, converge inwards radially.

An ommatidium (fig. 33) is a definite arrangement of five kinds of cells in a cluster about a central axis. The cells comprising each ommatidium may be enumerated as follows:—(1) Corneal hypodermis (secretes the facet of the cornea immediately above it); (2) Cone cells; (3) Distal retinular cells (Iris cells, Hesse); these three kinds constitute the dioptric portion of the eye; (4) Proximal retinular cells, which, together with the rhabdome, constitute the receptive portion of the eye; (5) Accessory cells (Tapetum cells, Hesse).

(1) According to G. H. Parker there are two *corneal cells* (*c. hy.*), and the fine line bisecting the facet of the cornea is the line of their division, but Schneider states

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* See also Note, on p. 567.

that they are four in number. These cells are squamous and tile-like, but their boundaries are very indistinct.

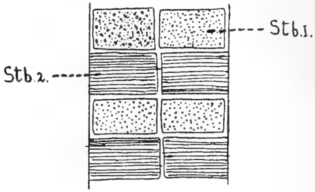
(2) The *crystalline cone* (*vit.*) is composed of four cells, and it extends from the corneal cells to the distal end of the rhabdome. Each cone cell has a transparent body tapering to its proximal end, which overlaps the distal end of the rhabdome. The nuclei are at the distal end of the cells.

(3) There are two *distal retinular cells* (*d. re.*) at opposite sides of the cone cells. They are deeply pigmented and are contractile, their size varying with the strength of light.

(4) There are seven *proximal retinular cells* (*p. re.*), and Parker has found that there is typically an eighth which has become rudimentary. These cells surround the rhabdome. Their distal ends—by the side of the cones—are bulbous and contain the large nucleus, the proximal end tapers off above the basement membrane. The optic nerve fibrillae pass through the cells to end in all probability in the "stiftchen" of the rhabdome (fig. 33). They run up the outside of each retinular cell, pass round the nucleus and return down the inner side. It is this bundle of fibrillae round the nucleus which gives the bulbous appearance to the distal end of the cells.

The retinular cells are deeply pigmented from end to end and thus form a complete dark sheath round the rhabdome. Parker found that in the darkness the pigment migrated completely into the retinal fibres beneath the basement membrane, so that the rhabdome became accessible to light from all sides. Similar changes are induced by darkness in the distal retinular cells (Iris cells), the pigment all retreating into the body of the cell at its distal end. In daylight the pigment extends down the proximal processes of the cells.

The *rhabdome* is a complicated structure, narrow and spindle-shaped (figs. 33 and 34 and Text-fig. 2), which used to be described as consisting of four parts, a fact which induced Grenacher to conclude that it was secreted by alternate retinular cells. It is now known that the quadripartite appearance and form is illusory, and is due to the peculiar manner in which the retinular cells form the structure.



TEXT-FIG. 2.

Every two retinular cells (reckoning the seventh one as double) take part in the secretion of one quarter of the rhabdome. These quarters—which may be separated and are known as rhabdomeres—are each made up of transverse plates alternately supplied by the two cells (fig. 34). Any one retinular cell would have a toothed or cogged appearance if it were separated with its own portion of the rhabdome. The whole rhabdome therefore is built up of a series of transverse half-plates and Text-fig. 2 would represent a diagrammatic eccentric longitudinal section in which the " stiftchen " of each lamella are shown alternately with cut ends and from the side. The arrangement reminds one of the dovetailing of the edges of a box. In transverse section the rhabdome is almost square, and it is surrounded by a distinct investing sheath (" Schlussleisten," Schneider). Each of the half plates bears a border of "stiftchen," and it is probable, though not certain, that the nerve fibrillae, passing through the retinular cells from the optic nerve, communicate with them. At the distal end of the rhabdome is a pear-shaped cavity, first described by Parker, filled with a coagulable fluid (fig. 33).

(5) Irregular cells, lightly pigmented, are found at the base of the rhabdome and on both sides of the basement membrane. Parker, who calls them *accessory cells*, thinks they are probably mesodermic. The nerves from the ommatidia pass into a mass of nervous tissue, underneath the retina, which contains four successive ganglia, and thence to the brain.*

Various observers have given conflicting accounts of the type of image which is thrown on the retina of the Arthropod eye. From the most recent researches, however, there is little doubt that the image in the compound eye is a single upright one for the whole retina, whose perceptive elements, the rhabdomes, receive each a single impression. Parker has succeeded in obtaining all the results of previous observers by preparing the eye in different ways, and by pointing out where they failed has practically proved that each ommatidium does not receive a small complete image.

THE OTOCYST (figs. 35 and 36).

The otocyst or auditory sac is situated in the proximal joint of the first antenna. There is a small bulbous prominence on the outside of the joint in which it lies, and it opens to the exterior by a narrow

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* The classic paper on the Arthropod eye is by Parker in the *Bull. Mus. Comp. Anat.*, Harvard, Vol. XXI, p. 45. In details of finer histological work it has been superseded by Parker's further paper in *Mitt. a.d. Zool. Stat. z. Neapel.*, T. XII., 1897, and by Hesse's in *Zeit. Wiss. Zool. Wien.*, Bd. LXX., p. 347.

longitudinal slit on the dorsal surface, two-thirds up the joint from the posterior end. The opening is guarded by two fringes of setae, an upper fringe of simple styliform hairs springing from the inner edge and passing diagonally forwards across the opening, and a lower fringe of large, somewhat fusiform, densely plumose hairs springing from the outer edge of the opening, and directed at right angles to the upper fringe.

The otocyst itself is attached by its anterior end, underneath the opening to the exterior, and extends backwards for about one-half the length of the entire joint. It is a simple gourd-shaped sac with chitinous unfolded walls, which are often—with the exception of a small portion of the dorsal surface—lightly calcified. The stalk of the gourd is at the extreme posterior end of the sac, and is turned towards the mid-line, so the sac appears to lie on its side. This small caecum has been unfortunately named the "cochlea," in reference to an imaginary resemblance to that structure of the vertebrate ear. The interior of the "cochlea" is always minutely spinose. A slight carina runs from the "cochlea" round the outer side of the sac, and a shallow groove from the same point along the ventral side contains the otic branch of the antennulary nerve.

The interior of the sac is not complicated by any irregularities, but follows precisely the lines of the outside. The sensory region is to be found on the floor, and the special "auditory" setae are roughly arranged in two or three rows diverging from the "cochlea"; the greater number of setae spring from the slight ridge of the otic nerve on the outer side of the sac, while the remainder are placed in an irregular row on the inner side supplied by a smaller nerve branch. They are of one kind only—small, straight and plumose, miniatures in all but the base, of the fringing setae already described (fig. 36). Each hair is a hollow tube attached by a membranous base to a knob-shaped podium, in which the single nerve fibre supplying the structure terminates. Thus the hair is only capable of extensive lateral movement at the membranous base in direct contact with the nerve element.

Many sand particles, of all sizes small enough to enter by the orifice, are found free in the lumen of the sac or adhering to the setae. The nerve supplying the sensory region impinges on the sac at its posterior end on the ventral surface, and at once divides into a more ventral broad portion which curves nearly round the outer side of the sac, and a smaller branch passing to the inner side.* It is unnecessary to deal with the functions of the sac in detail. Prentiss† gives an exhaustive account of the work of earlier observers and supplements it with his own experiments. A feeling for the picturesque in the earlier naturalists, aided by inconclusive experimental work, led them to assign a sense of hearing to Crustaceans only differing in degree from our own; but, after a period in which both opinions were held, the general view now is that the otocysts are almost exclusively static in function, and are only concerned in the orientation of the animal.

Olfactory and Tactile Setae.

Other sensory setae of a simple kind are found in most parts of the body. They consist of a hollow shaft, which communicates with a single nerve fibre. On the

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* An inaccurate account of the otocyst of this species (under the name *P. streblonyx*) by Farre, may be found in *Phil. Trans. Lon.* 1843.

† *Bull. Mus. Compar. Zool.*, Harvard, Vol. XXXVI., No. 7, p. 168, 1901.

first antenna another type of setae is found. They are in a dense bunch on the upper side of the exopodite and are known as olfactory setae. Each seta is a long, tapering, flattened shaft, with a large number of joints—about two dozen—placed on a wide base. It is hollow and appears to open by a minute pore at its distal end. Round each basal joint is a small bunch of minute hairs. The exopodite is a strongly annulated conical structure, and each ring bears several of these long setae. In life the crab continually flicks its antennules, spreading the setae at each flick. Each seta is supplied with a large number of nerve fibres.

MUSCULAR SYSTEM.

It is unnecessary, for the purposes of this Memoir, to enter into a full description of the muscular system of the Hermit Crab. A detailed account of the muscles of a fairly typical Decapod Crustacean has been given in the Memoir on Cancer*; and though the present type has closer affinities with the Macrura than with the Brachyura, so far as the present system is concerned, no useful purpose will be served by enumerating muscles which have their counterpart throughout the Order. Certain parts, however, of the muscular system have undergone profound modification due to the mode of life of the animal, and of these parts an account, based entirely on M. T. Thompson's† work on the metamorphosis, will now be given.

It is the musculature of the abdomen which diverges in the greatest degree from the normal. As practically all the movements of the abdomen are confined to flexion, the flexor muscles have become abnormally large

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* Pearson, "Cancer" *L.M.B.C. Memoirs,* XVI.

† *Boston Soc. Nat. Hist.,* Vol. XXXI., No. 4, p. 147.

at the expense of the extensors. The muscles of the young animal in the early Glaucothoë stage only differ in detail from those of the Crayfish or Lobster. The extensors have a general longitudinal course and are well developed; the flexors comprise several muscles, the descending, transverse, longitudinalis and loop-enveloping, and pleopodal muscles independent of the flexors are present.

In the change to the adult crab the transverse muscles lose their fibres and disappear, and only remnants of the descending and lateral longitudinal muscles persist, so that the flexors come to consist of the ventral, longitudinal and the loop-enveloping muscles, the former of which are probably the more important. The pleopodal muscles also degenerate and the extensors are extremely weak. A thin layer of fibres—the integumentary muscles—lines the integument beneath the nerve cord; they are apparently derived from scattered fibres that lie in the same position during the Glaucothoë stage. The columellar prominence is derived from the ventral flexor muscles of the third segment. The flexors are bulky, and those of the right side are considerably larger than the flexors of the left.

There is nothing in the muscles of the cephalo-thorax which calls for comment.

REPRODUCTIVE ORGANS (Pl. V).

With the exception of the orifices of the sexual ducts, there is only one point in which the male *E. bernhardus* differs in external characters from the female. That difference is to be found in the abdominal appendages, so it is quite impossible to distinguish the sex of a Hermit Crab unless it be extracted from the shell; but the right chela of the male is often more massive than that of the female. The male always shows much greater readiness to emerge from its shell than the female, especially if she be "berried." The pleopods of the female are four in number; they are on the left side only on segments two to five. The male has three pleopods, that of the second segment being absent, and they are all much smaller than the first three of the female. The fourth pleopod of the female is as much reduced as those of the male.

MALE SYSTEM.

The **Testes** (figs. 25 and 40) are paired and quite separate. They lie in or about the third segment of the abdomen, and the vasa deferentia open by a circular hole on the base of the last pair of pereiopods. Both organs are placed in the cleft between the two lobes of the digestive gland, the left on the dorsal side and the right against the muscles. Owing to the twist of the liver, the left testis has become topographically dextral to the right one. Both testes are flat, lozenge-shaped organs, and the superficial left one is slightly larger than the right, which is imbedded in the digestive gland in a laterally erect position. The vasa deferentia are large, prominent yellow tubes in the breeding season. They pursue a tortuous course till they reach the thorax, when they abruptly plunge downwards to the external opening.

Each testis is essentially a long and excessively convoluted tube, in the length of which the sperms may be seen in every stage from their origin as spermatoblasts to their final condition in their chitinous case. The greater part of the testis—the testis proper—is a narrow lobulated tube, which has become so intensely convoluted and involved that it has the appearance of a solid mass. It is impossible to unravel this tangle, and the tube may or may not branch.

It is from the epithelium lining this portion of the testis that the gonadial elements arise. Some of the germinal epithelium cells enlarge greatly and are budded off into the lumen of the tube. These bodies have a large quantity of densely staining nuclear matter and scanty cytoplasm. They pass further down the tube, and each divides into many smaller bodies with large deeply-staining nuclei and again but little cytoplasm, and each of these in turn gives rise to a single spermatozoon. The former large bodies, which are more abundant in the higher reaches of the tube, are known as the *spermatocytes*; the smaller bodies formed by their division as the *spermatids*. A typical section through a testis follicle usually shows a large number of either spermatocytes or spermatids with spermatozoa (fig. 46). It is not often that both conditions are found in equal quantities in any one portion of the tube.

The spermatozoa continually pass down the germinal portion of the tube into a smooth, thick-walled area in which the chitinous cases for their reception are secreted. The epithelial cells lining this part are extremely long with oval nuclei situated at the end of their outer third. The cavity has become constricted and plum-stone shaped. The tube presently emerges from the tangle and is seen to be a continuation of the vas deferens. The portion in which the preliminary process of forming the spermatophores is carried on, lies in a very compact small coil on the surface of the general mass of the testis at its posterior end (*d. c.*, fig. 40), and in this coil the sperms are surrounded by a long smooth chitinous case, which is uninterruptedly continued until the tube begins to leave the above-mentioned compact coil and pass forward as a more or less straight duct.

At the beginning of this straight portion signs of segmentation begin to appear on the upper side only of the chitinous tube containing the sperms (fig. 41). These constrictions deepen till the sperm band presents very much the appearance of the colon of higher mammals, and finally it becomes cut into a series of lobes united by a continuous base—each lobe containing a large number of spermatozoa (fig. 42). The lobes, as we go further down the tube, gradually assume the shape of the finished spermatophore (fig. 43), and on reaching the vas deferens, the strip of membrane on which they are placed like a fringe breaks into convenient lengths—four or five spermatophores being placed on each strip.

The vas deferens, which is crowded with such strips, is a thin-walled broad tube of considerable length. It becomes narrower on reaching the thorax and this narrow part is continued to the communication with the exterior—it is called the *ductus ejaculatorius*. The whole gonad from the germinal portion to the end of the ejaculatory duct is one uninterrupted tube.

Spermatozoa (fig. 44, *a* and *b*)—The sperms are quite characteristic bodies. They appear, in the living material, to consist of a clear capsule from which spring, near the base, three long processes. Stained preparations show that the detailed structure is based on the same lines as those usual among the marine decapod Crustacea. There is a vase-shaped head, down the centre of which runs a hollow column with dorsal and ventral orifices. The cephalic vesicle is clear and it rests on a collar from which three processes spring. Under the collar is a somewhat irregular vesicle of granular protoplasm, which readily stains. Retzius describes an anterior explosion capsule and figures various stages in its development.*

FEMALE SYSTEM.

The **Ovaries,** like the testes, are situated in the abdomen, their ducts passing forwards into the thorax to open on the coxa of the third walking leg. They are also quite separate, and although the oviducts are very close to each other, they are never connected, a condition which seems to be uncommon but not unique in the Decapoda. In a mature specimen the ovaries take up a large part of the abdomen, both right and left gonads extending throughout its length. They are irregularly disposed, the left organ lying above its fellow at the anterior end, and, more posteriorly, on the right side of it.

Both organs are sausage-shaped bags of a deep purple colour in the living specimen. They present a granulated appearance when mature and the separate ova can be readily distinguished, but when spent they shrink to a fifth of their normal size, and are then a pale reddish colour. The oviducts are simply anterior prolongations of the ovaries. They arise without any very definite break and pass to the opening to the exterior without any convolution whatever. The internal structure of the ovary is not essentially different from that found in other Decapods.

The young eggs arise from a narrow band of epithelial tissue on the inner side of the ovary, extending its entire length. Although it is typically peripheral in position, in a mature ovary the crowding of the large eggs constricts its base and forces it to occupy a more

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* Retzius. *Biolog. Untersuchungen*, Neue Folge, XIV.

nearly central position.* This band of tissue has been called by Ishikawa† the "germogen," to contrast it with the "vitellogen"—the rest of the ovary where the yolk elements are found. It is transparent in the fresh condition and is readily distinguishable from the purple eggs; in preserved material it is even more distinct, showing up white amidst the red ova. The ova in the ovary are enclosed in a follicular epithelium. The cells which are about to form the follicles are almost indistinguishable from the very young ova. The mature eggs are crowded together closely, and partly lose their rounded form by mutual pressure. The protoplasm of the ovarian egg has a characteristic radially striated appearance, and there is a membrane enclosing the egg—the primary egg membrane—which arises apparently from the peripheral protoplasm. A second membrane of a tougher nature, which is probably secreted by the cells of the oviduct, is present on the ripe egg. The walls of the oviduct before oviposition are very glandular. P. Mayer correctly states that there is but a single nucleolus in all the stages of the ovarian egg, and he also says that the freshly laid egg is not furnished with a nucleus and is a cytode. It is well known, however, that the chromatin of the germinal vesicle is often lost during maturation, and it is this phenomenon probably that accounts for the condition to which he refers.

The **"Cement" Glands** on the under-surface of the abdomen are accessories to the reproductive organs proper. They all consist of the type of gland we have noticed before—that is to say, a globular structure of pyramidal cells from the central cavity of which an

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* Cf. Bumpus, American Lobster. *Journ. Morph.* V., p. 215, 1891.

† *Quart. Journ. M.S.* XXV., p. 391, 1885.

intracellular duct leads. The glands, which are profusely scattered on the under-surface of the abdomen in the dermis, secrete a mucous fluid which has been assumed to be the medium by which the eggs are attached to the pleopods. The exact method of attachment is still unknown, and nearly every observer of the egg-laying has a different theory of fixation. Huxley in his "Crayfish" considers that the eggs are coated with a viscid matter as they leave the oviducts* and Lereboullet, who has observed the process closely, is of the same opinion. The latter observer states that the cement glands are for the purpose of filling the "brood chamber" with mucus in which the eggs and sperms mix, and it is highly probable they have the same function in the Hermit Crab.

DEVELOPMENT (Pl. VI).

It is not known how fertilisation is effected in the present species. Copulatory organs are altogether absent, and neither the transference of the sperms nor the act of oviposition has ever been observed. Mayer (see below) argues from the apparent impenetrability of the outer coat of the egg when it leaves the oviduct that fertilisation must be internal. He is unable to offer any explanation of the method by which the free sperms gain access to the ovary. There seems no good reason why the egg coat should be considered to be more impervious to the sperms in Eupagurus than in the Lobster or Crayfish. In both of these animals fertilisation is undoubtedly external, and in the case of the Crayfish every step in the process has been observed. It is not possible for the Hermit Crab to form a brood pouch by flexing its

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* Bumpus (loc. cit.) comes to the same conclusion with regard to the American Lobster.

abdomen in the same way as the Crayfish, without suffering some loss of the eggs, but the very fact that the cement glands are placed on the under-surface of the abdomen, instead of in their usual position on the pleopods, suggests that a similar process is gone through. Experiments on a female Hermit Crab will show that though glands on the pleopods would not be much use in filling a brood pouch formed by the flexion of the abdomen with secretion, similar organs on the under-surface of the abdomen would be very efficacious for that purpose. Fertilisation in such a chamber would be just as possible in Eupagurus as it is in the Crayfish. The empty spermatophores are almost always to be found adhering to the pleopodal eggs, and they can only have got there during oviposition. It is possible that the extended breeding season of this species is not unconnected with a certain wastage of eggs.

In brief, the process as conceived above would be as follows:—The male deposits the spermatophores on the under-surface of the female (possibly in a space between the columellar muscle and the body into which the oviducts open when the tail is flexed); the female flexes her abdomen underneath the thorax, fills the space with mucus, dangles her pleopods into the chamber and pours out the ova. The ova and sperm are mixed in the chamber, as in the Crayfish, and the eggs become attached to the pleopods, also as in that animal. The process of oviposition might possibly be carried on inside the whelk shell without flexing the abdomen.

Embryonic development.—The eggs are attached to the setae of the pleopods on the second, third and fourth abdominal somites in dense purple clusters.* Up to the

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* The ova of *E. prideauxii* seem to be red, both ovarian and after extrusion.

eighth stage cleavage is total but somewhat abnormal, the nuclei dividing more rapidly than the blastomeres are formed, so that it is not before eight nuclei are present that segmentation occurs. The yolk is present in the cells as small fat bodies. The separation of yolk matter and protoplasm takes place on the egg dividing for the fourth time, and the nuclei becomes peripherally arranged, surface furrows indicating the boundaries of the cells. From this point segmentation is superficial. Gradually the centre of the egg breaks up and the protoplasm becomes confined to the single layer of cells on the outside, which encloses the yolk. It is unnecessary to follow the development further in detail, as it is quite normal from this stage.* A germinal disc appears, in the centre of which an invagination of the blastoderm forms a shallow gastrula. In front of the gastrula is the "anlage" of the abdominal region and further forwards the paired "anlagen" of the cephalon. The mesoderm proliferates from the cells in the front half of the gastrula and spreads forwards into the cephalic region. The gastrula cavity now closes and the hypoblast absorbs the yolk matter, pressing the epiblast to a thin surface layer. An invagination in front of the blastopore becomes the mouth and fore-gut, while the blastopore itself become the anus and hind-gut. The future mid-gut is formed as usual from the invaginated hypoblast.

Post-embryonic development.—The breeding season of Eupagurus is very extended, and at almost any time of the year females may be seen with eggs attached. The Zoeas are to be found in tow-nets from April to the end of September, and the Glaucothoë stage even later.

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* Further details may be obtained from P. Mayer's paper in *Jen. Zeitschr. f. Naturw.*, Bd. XI., p. 188, 1877, from which the above account has been summarised.

The larvae are very delicate and difficult to rear in confinement, but one can get every stage in abundance in the plankton at Port Erin. The eggs remain on the pleopods until hatching time. The little Hermit Crab is now in the Protozoea stage, but the first ecdysis is accomplished as the larva quits the egg capsule, so the first free stage is in the form of a Zoea. To set the larvae free, the mother sits partly out of her shell and wipes the pleopods gently with the brush of setae on her last pereiopod to facilitate their escape. The same appendage serves to remove the husks from the pleopodal setae when the hatching is over.

A berried crab often exposes her eggs when her surroundings are peaceful, and fans them slowly up and down in the water by moving her pleopods. At an average the mother crab has about twelve to fifteen thousand eggs attached to her abdominal limbs at one time. Only a brief summary of the post-embryonic development can be given here; a detailed account of the American species *E. longicarpus*—which seems to agree in all particulars with ours—is given by M. T. Thompson.*

Six larval stages can be distinguished in the course of the development, four Zoea stages, a Glaucothoë, and a group of adolescent stages. The Zoeas of *Eupagurus* are very characteristic and can be picked out by the unaided eye in a miscellaneous assemblage of small Crustacea by their shape alone. The carapace is large and free from carinae or spines. It is excavated, not deeply, at the back, and as a result there are two latero-posterior, prominent pointed projections, which, however, are never prolonged into spines.

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* *Proc. Boston Soc. Nat. Hist.* vol. XXXI., No. 4, p. 147.

The rostrum is fairly long and pointed. The whole carapace is smooth and quite free from minute denticulations. Each abdominal segment has two small dorsal and four lateral projections (two on each side) on its hind border. There are two fixed telson spines* on either side, the inner one straight and spinose, the outer smooth and curved, and a number of other spines, according to the age of the larva. A small hair-like process springs from under the outside spine on each side. The telson is a very characteristic spatulate shape with a median marginal notch in its posterior edge. There is a characteristic and obvious difference between the telson of this species (*E. bernhardus*) and that of the nearly allied *E. prideauxii* (figs. 48 and 49). The telson of *E. prideauxii* is shorter and more triangular in the first Zoea stage than that of *E. bernhardus*, but a more striking divergence is seen in the spines on the telson. The first Zoea of *E. bernhardus* has altogether six spines on either side of the median notch, and the third from the outside has no suture between it and the telson, and is half as long again as the inside spines. The same spine in *E. prideauxii* is equal in length to the other spines and is jointed to the telson. The proportion of length holds good through all the stages. The uropods of the later stages also differ. The living Zoea is transparent and has a patch of reddish yellow pigment under the dorsal side of the carapace. The eyes are compound and black, with a narrow yellow surround; two red spots are often present under the eyes on the mouth region.

The six larval stages may be distinguished by the following characters:—

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* i.e., spines which do not articulate with the telson.

First Zoea.*—The first and second maxillipedes are developed and their exopods bear four feathered setae (fig. 56, Pl. VI). No thoracic limbs are present. The telson has four articulated and two telson spines on either side of the median notch (fig. 48). Only five abdominal segments can be distinguished, the sixth is fused with the telson.

Second Zoea.—Three maxillipedes are present and the rudiments of the thoracic limbs have appeared. Exopods of maxillipedes have six setae. The "anlagen" of the uropods present in early stages, and in late ones the rudiments of the limbs may be seen through the integument. Two extra spines appear on the telson (fig. 51).

Third Zoea.—The exopods of the maxillipedes have seven or eight setae and the uropods are present. The sixth segment of the abdomen is distinct. Gill rudiments are present on the limbs.

Fourth Zoea (Metazoea) (fig. 47).—The thoracic limbs are quite distinct and the fifth pereiopod, which is tucked up under the body, is chelate (fig. 50). The chelipedes are unequal. Rudimentary pleopods are present.

In organisation the Zoea stages do not differ from the others of their type among the Brachyura and Macrura, but in the next stage a complete metamorphosis is undergone and the great modifications in the structure of the adult Hermit Crab make their appearance.

The Glaucothoë was for a long time ranked as a distinct species of animal, chiefly because of its comparative scarcity. The scarcity was only apparent, however, because of the habits of the animal, and when

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* Figures of the Zoeas and Glaucothoë of *E. longicarpus* may be found in Thompson's valuable paper (quoted above) and in: Faxon, Embryological Monographs, 1. Crustacea. *Mem. Mus. Comp. Zool.*, Harvard, Vol. IX, No. 1, 1882.

a suitable time and method for catching them is chosen, they can be obtained in large numbers. Like the fresh-water Mysis, they spend the day at the bottom of the sea and rise to the surface at night. The Glaucothoë has a carapace, of adult shape, but the branchiostegite is not bent down at right angles to the cephalic shield. Pleopods are present on all but the first abdominal somite, and the right uropod is smaller than the left. The otocysts have now appeared. It is during this stage that the animal first seeks a moveable residence and the larvae spend their time in alternately prowling on the bottom and swimming about. The stage usually lasts four or five days, and in that period the livers, excretory bladder and gonadial organs shift to the abdomen, while the more superficial structures undergo degeneration. The abdominal muscles become modified, the right pleopods disappear, and those on the left side degenerate. The metamorphosis is not dependent on a body covering, but completes itself even if the animal is kept naked, although the stage lasts much longer (up to six or eight days) and the mortality is very high.

"The anatomical modifications that appear during the Glaucothoë stage are, with but one exception, uninfluenced by either the presence, absence or form of the shell. The exception is found in the retention of rudimentary pleopods on the right side of the body in the sixth stage, though typically at this period appendages should be absent from this side."—(Thompson.)

Adolescent phase.—In this stage the typical adult structure is attained. The organs develop completely and the pleopods definitely show the sex of the animal, but Thompson finds that sexual maturity is not reached till a year or more after the moult from the Glaucothoë stage to the young adult.

BIONOMICS AND ECONOMICS.

The hermit crab has suffered from the neglect so commonly meted out by competent zoologists to animals whose peculiar habits have attracted the attention of the unscientific observer. There is consequently a large mass of undigested facts and fables concerned with its mode of life and habits, and an equal paucity of accurate morphological data. The most remarkable precocity has been attributed to this creature, with no regard for the comparatively lowly position it fills in the animal series.

I have not come across many early references to the hermit crab. Aristotle notices two species—probably *E. bernhardus* and *Diogenes varians*—briefly and indifferently well. He found them in the shells of Strombus, and remarks on the softness of the exoskeleton, the fact that they are not attached to the shell they occupy but change as they outgrow it, their possession of an oesophagus which leads into a stomach—there is no recognition of a gut or an anus—and finally, the astonishing statement that some anomuran, it is not clear which, casts a web across the mouth of its habitation to capture its prey. He considered these animals to be intermediate between the Mollusca and Crustacea, and that they originated, like the former group, from mud and sand.

Swammerdam (1738) was the first to make a scientific investigation of the hermit crab's anatomy, and except for one terrible mistake (referred to below) his work was very advanced. The account of the nervous system is especially good, and his careful dissection prevented him falling into the serious errors committed by Gegenbaur and Claus, among others, which have found their way into modern text-books.

Its Habitation.

The possession of a shell of foreign origin has probably had more share in attracting the attention of naturalists to the hermit crab than any other of its habits. The tenant's right of ownership was the chief problem. Swammerdam went so far as to argue that the shell was actually secreted by the inmate, and supported his contention by various ingenious arguments. Later observers took the less charitable but, unfortunately for the animal's reputation, the more tenable view that the shell had been obtained from a friendly or perhaps a much wronged Gastropod Mollusc. Whether the crab had simply appropriated the vacant home of a deceased whelk, or whether it had forcibly ejected the owner of the shell—added "murder to piracy"—was the question to be decided.

Bell argued from the fresh and clean shells in which hermits are frequently lodged that they attack the living mollusc and eat it out of its home. In fact, he considered that they are designed to keep the mollusc population in check. This idea seems to be strengthened by the fact that fishermen sometimes trawl the animals in the act of eating the whelk from its shell, presumably in anticipation of using it for a covering. Bell's argument and the fishermen's observation are quite accurate, but they do not prove that the hermit crab attacks the living Gastropod. In the first place it is not very conceivable that a hermit crab would have the strength to remove bodily, or the appetite to devour, an extremely tough animal like the whelk. Such an objection, however, does nothing to elucidate the facts which have been stated, but I think the following suggestion will go a long way towards meeting them.

It is well-known that the cod feeds very largely on the whelk, and that nothing but the operculum is ever found in the fish's stomach. The mollusc's fleshy portion (chiefly the foot and head) must therefore be bitten off while expanded—a comparatively simple matter to the active and powerful Teleost—leaving the softer (visceral) parts inside the shell. There is no doubt that the hermit crabs might then eat out these softer parts, and afterwards ensconce themselves in the new shell. I do not wish to imply any necessary connection between the adoption of a new shell and the emptying of its contents; in fact my observations all go to show that the crab will accept any covering rather than delay to clean a shell, let alone wait to dine off the contents. Thompson's experiments have led him to the same conclusion.

Choice of Shell.

The young Eupagurids have a much larger field of choice in the species of shell they inhabit than their elders have, and in addition the young whelks and other small Gastropods have many more enemies than the more powerful adult whelks. The full-grown *Eupagurus bernhardus* always seems to prefer the shells of *Buccinum undatum* (the common whelk), and *Fusus antiquus* (the hard whelk), above all others for a home; in fact, his bulk at maturity leaves him little choice. Among the many score of specimens I have examined, only two were in other shells, and each of these had chosen a very large example of *Natica nitida* for his abode. *E. prideauxii* is much less fastidious in its choice of a house than its martial brother, owing partly to the fact that the animal never attains the same size when fully grown, but still more to the investing anemone which makes the possession of a full-sized shell of secondary importance. The young *E. bernhardus* is able to select from a large number of species. I have found specimens commonly in the following, but they use almost any shell or hollow object of suitable size and shape.

Buccinum undatum (young).
Fusus antiquus (young).
Murex erinaceus (young).
Natica nitida.
N. monilifera.
Littorina littorea.
Dentalium entale (rarely).
Purpura lapillus.
Trochus cinerarius.
Nassa incrassata.
Turritella communis.

BIOLOGY OF THE SHELL.

The possession of a shell is a matter of importance to the hermit crab, not solely for its protective value, but also because it seems to concern its health. Although crabs may be kept naked for a considerable time if they are solitary and in suitably inoffensive surroundings, they weaken in time and eventually die. To keep them without covering in company, or with rough and jagged surroundings, is rapidly fatal, as the delicate abdomen is very easily ruptured, and death invariably follows. M. T. Thompson has experimentally studied the effect of the shell on the metamorphosis, with valuable results. His conclusion is: "The stimulus of a shell is not necessary for the completion of the metamorphosis any more than for its inauguration," but the change from the Glaucothoë to the adult is delayed on the average by the absence of a shell, and the health of the larva is deeply affected. His experiments on naked larvae show most distressing mortality. The shape and nature of the covering seems to matter little, either in respect of form or health, so long as one is present.

It is almost impossible to describe the crab's manner of vaulting into its shell. Its humour can only be appreciated by one who has seen it and can contrast the animal's previous nervous anxiety (Taylor uses the apt simile " A bather whose clothes have been stolen!") with its sleek impudence on safely reaching the desired covering.

The crab is extremely difficult to remove from its shell. Even if it is prevented from using the telson and uropods it will hold on quite effectually by flexing its abdomen strongly and elevating itself by its last two pereiopods against the roof of the aperture. The best way of getting it out of the shell is to break away the opening till the front of the animal is exposed, and then to insert a seeker and gently tickle the abdomen. The crab usually makes a rapid egress without rendering further resource to the bone-forceps necessary. Any other mode of removing it, apart from entirely breaking up the shell, is useless and generally ends in the parting of abdomen from thorax. Nevertheless their fellow hermits are sometimes able to do what man finds beyond his powers. The whole battle seems to lie in a sudden and unexpected onslaught, for if the crab has any suspicion of foul play it will not venture outside the inner whorls of its house; no further, in fact, than where it can still retain a firm hold.

In spite of the cumbersome shell the hermit crab is very nimble in its actions. I have seen individuals climbing steep faces of rock—the shell pendant behind them—which would have presented difficulty to a less severely handicapped crustacean.

The inside of the shell is kept aerated by means of the current of water from the branchial chamber, aided by the pleopods which lazily flap to and fro while the animal is resting. The fact that *Anomia* is found quite far back in the shell, and that various small animals live in the last whorls of it, shows that the water must be fairly fresh.

It is not known how the faeces are disposed of. Possibly there is not enough waste matter to cause any serious nuisance, and the small Amphipods in the shell might conceivably remove some of its objectionable features.

Dr. Gray* long ago made the curious observation that hermit crabs have the power of dissolving the shells in which they live. He says that the lip and pillar on the inside of the mouth is often destroyed in the shells inhabited by this animal. It seems more probable that a partiality for old shells on the part of the crustacean, or a local scarcity of suitable shells, accounts for the fact. It is very unlikely that any "faculty for dissolving shells" is possessed by the hermit crab. The roughening of the internal surface he remarks on is caused by the scraping of the uropods and pereiopods.

Its Food.

The Hermit Crab is an omnivorous feeder. In its early youth it follows the cannibalistic instincts of other Zoeas, but the adult seems to be purely a scavenger. It will accept almost any animal or vegetable food. The left chela is almost invariably used for carrying the food to the foot-jaws and it also aids them in tearing the morsels to suitable shreds. It may be observed very frequently tossing sand with the same appendage between the mouth parts, and letting the grains drop as it rubs

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* *Ann. & Mag. Nat. Hist.*, ser. 3, vol. 2, p. 164, 1858.

them. There is no doubt M. T. Thompson is right in thinking that the diatoms and foraminifera which are found in the alimentary canal come from this source.

COMMENSALS.

Although *E. bernhardus* does not exhibit such apt illustrations of commensalism as some of its allies, it usually contrives to entertain some stranger in its abode. To the human observer, however, it has seemed less happy in its bargains than they. The Polychaet worm *Nereis* (*Nereilepas*) *fucata* is found in many shells. J. Hornell[*] states that 90 per cent. of the shells which have been taken possession of by hermit crabs contain the worm, but my records—made from the examination of a large amount of material—show that in not 30 per cent. were these animals found associated. The frequency of this case of commensalism on the South Coast is evinced by Gosse's observation that the fishermen of Weymouth are accustomed to break open the hermit crab's shells for the sake of the worm inside.

The Nereis usually remains out of sight in the back whorls of the shell, but it appears at meal times, thrusting its head out between the crab's foot-jaws to appropriate the very morsel on which its host is engaged. In several young crabs' shells (Littorina and Natica) I found young *N. fucata,* about half an inch in length. It would seem, therefore, that the worm changes house with its host as both grow up. It is difficult to suggest any advantage that the hermit crab can gain from the presence of this guest.

E. bernhardus is also found associated, but not in the L.M.B.C. district, with the sea-anemone *Sagartia parasitica.* It carries the coelenterate turretwise on top

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[*] Fauna of Liverpool Bay, Rep. III. *L.M.B.C.* 1892, p. 126.

of its shell, in a manner most strikingly unlike the relations of its near ally *E. prideauxii* to *Adamsia palliata.* Here again the soldier crab seems to have been unfortunate in its choice of a partner, for the gain, as in the case of the Nereid, seems to be entirely on the side of the anemone. I have found one specimen of *E. bernhardus* with *Adamsia palliata* attached to its shell. The *Adamsia* was spread, like a table-napkin, over the lip of a full-grown whelk shell, making a sort of cushion for the crab to rest upon.

Not infrequently specimens are found—chiefly in shallow water—whose shells are covered with a colony of *Hydractinia echinata.* In some districts over 50 per cent. of the shells have this growth upon them; in others, specimens with it are infrequently obtained. Henderson* records rare instances of *H. echinata* being found along with *E. pubescens.* A combination which less frequently occurs is that of *E. bernhardus* with the sponge *Hymeniacidon suberea.* Only young specimens seem to carry the sponge, and the occurrence of the combination is most sporadic. Off Port Erin a haul of the dredge will sometimes be taken in which nearly every *E. bernhardus* is associated with this slimy red sponge.

There are other animals which are present in or on the shells inhabited by the soldier crab which are more casual than those which have been cited, and which come more strictly under the head of chance association than commensalism. The frequent presence on the shell of tube-building worms, and in the shell of the mollusc Anomia, Amphipods, and small crabs, are cases in point.

Pomatoceros is found both inside and outside the

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* Decapod and Schizopod Crust. of Firth of Clyde. *Trans. Glasgow Nat. Hist. Soc.* 1886.

shells. I came across one specimen which had completely encircled the abdomen of its host in such a manner that the crab could not have moved without breaking the tube—a proof of either Crustacean idleness or Vermian hustle.

The Amphipod *Podoceropsis excavata* almost invariably infests the dirt at the bottom of the shells. A small crab which is not infrequently found with the Amphipod is the marble crab *Porcellana longicornis.*

Although this memoir is principally concerned with *E. bernhardus,* it will be of interest, while considering the commensals of the animal, to mention briefly some striking examples of the same phenomenon amongst other Pagurids.

One of the most familiar is the association of *E. prideauxii* with *Adamsia palliata,** a well-nigh perfect example of its class from the naturalist's point of view. When the crab reaches a certain size it ceases to change its shell frequently, but relies more and more on the covering afforded by the anemone. It comes finally, in some cases, to use the shell only as a grip for the telson, or even to discard it altogether. The anemone often secretes a membrane of hardened mucus, continuing the mouth of the shell outwards, which forms a complete investment for the crab and a definite support for the anemone. It is not probable that any absorption of the shell by the anemone can take place. It is now well established that this hermit crab achieves the apparently impossible by transplanting the anemone when it changes its shell. Gosse was the first to see the feat accomplished, and he gives a faithful account

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* For an excellent discussion of the relations between these forms and further details. see L. Faurot, in *Arch. Zool. expér. et gén.* Paris, ser. 5, V, 1910, p. 421.

of the proceeding in his quaint "Year at the Sea-side,"[*] The crab and the Adamsia are never found separated from one another, and their mutual companionship seems necessary for their existence.

A similar but even more remarkable case of commensalism is that recorded by Alcock[†] between *Chlaenopagurus*[‡] and a compound colony of Zoantharian polyps. The Actinian settles directly on the abdomen of its host, and grows over it imbedded in a copious fleshy coenosarc which the crab can draw over its head or throw back at will. There is no intermediate structure, such as the molluscan shell of *E. prideauxii*, to introduce the two forms. The crab simply pulls the coenosarc over its back like a cloak, and keeps it in position with his claws—"the polyps seeming to have no power of adhesion."

A nearer approach to the method adopted by Adamsia is seen in *Parapagurus pilosimanus*, which lives in the cavity in the coenosarc of a large Epizoanthus which had settled originally on the shell of the hermit crab, but had absorbed it on growing up. Other associations with Actinians are seen in *Pagurus striatus* and *E. excavatus* with the anemone *Sagartia parasitica*. *P. striatus* plants the anemone (which however, is independent of the association for its existence) on its shell in much the same fashion as *E. prideauxii* does the Adamsia, *i.e.*, by means of its chelae. The two species are often found living separately, and *P. striatus* does not confine its attention strictly to Sagartia.

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[*] An interesting but highly coloured note on the habits of this pair by Stuart Wortley may be found in *Ann. & Mag. Nat. Hist.* ser 3. XII. p. 388, 1863.

[†] *Journ. Asiatic Soc.* Bengal. Pt. II., No. 2, 1899.

[‡] This species is now included in Henderson's *Paguropsis*.

Besides the Hymeniacidon occasionally found with *E. bernhardus*, a species of Suberites (probably *S. domuncula*) not infrequently occurs in connection with *E. pubescens*. The sponge often completely absorbs the original shell of the hermit crab, leaving the crustacean in a smooth cavity in its interior. This crab is also found with the same Hymeniacidon which has already been mentioned in connection with *E. bernhardus*.

Some tropical forms which utilise the cavities found in corals and sponges can hardly be included under this section.

PARASITES.

I have found no internal parasites in the species under consideration, and I do not believe any have been recorded. Three external parasites are known. In the branchial chamber the Isopod *Bopyrus* is found, and on the abdomen *Phryxus paguri* and the degenerate Cirripede *Peltogaster paguri*.

As the last-named parasite has a remarkable and well-known effect on the generative organs of its host, it might be useful to summarise briefly the results of investigations which have been made on the subject.*

The infection by Peltogaster has the immediate effect of diminishing the size of the gonads, and at an early stage ova make their appearance in the glandular part of the testis. The male secondary sexual characters are stimulated to development towards the female type, and if the female is infected early a retarding influence is exerted by the parasite on its attainment of sexual characters. If the parasite be extirpated the modifica-

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* F. A. Potts. *Q.J.M.S.*, Vol. L., pt. 4, Nov. 1906, p. 599.

tions caused by it are retained. The changes are probably not due to the direct action of the Peltogaster, but are rather attributable to some change in the general metabolism caused by the parasite.

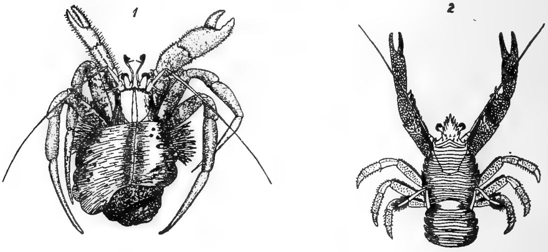
ECONOMICS.

The economic value of the hermit crabs, so far as their direct use to man is concerned, is almost negligible. Indirectly they are of some value since they form the staple food of the larger fishes—the remains of *E. bernhardus* are familiar objects among their stomach contents—and on some parts of the coast they are used by fishermen to bait their lines. Bell in his "British Stalk-eyed Crustacea" (1853) says, "The Hermit Crabs are much employed by the fishermen (who call them 'Wigs,' or possibly 'Whigs') as bait for cod; for which purpose they answer very well for immediate use, although the original possessors and builders of the house, the whelks, are much preferred for night-lines as remaining more firmly on the hook. They are taken in great numbers in prawn-pots for this purpose." This remark holds equally well at the present day.

Even now, for example, the fishermen of Port Erin make considerable use of hermit crabs during the winter, as bait for cod, ling, skate and other fish on their long lines. This is not a usual practice on the Lancashire coast, and the men do not bait with the crabs unless there is a deficiency of whelks, owing, they say, to the fact that the whelks remain longer on the hook.

At Port Erin the crabs are caught in the whelk pots, and are used along with the whelks as bait, but some of the men declare that the hermits are "the very best bait you can get for cod; none better!" When preparing the bait the man cracks the whelk shell with a slight blow from a stone or hammer, picks out the hermit and pulls the body apart at the peduncle or between the last two thoracic segments. The cephalothorax and its appendages are thrown away, and the soft abdomen only is put on the hook. The custom in Devon of breaking the shell to extract the Nereis within has already been referred to (p. 560).

Only one species seems to be used as food by the human race. The natives of the Islands of the Pacific, on which *Birgus latro*—the famous cocoanut crab—occurs, greatly prize the oily abdomen of the beast as a gastronomic delicacy.[*] The British Pagurids are not sufficiently common ever to be exploited commercially as a food for the table, but there seems no reason why such a clean and dry Crustacean should not make as delectable a dish as its more favoured Macrurid and Brachyurid relations.



ANOMURA.

[*] I have since seen an early description (*Zool. Journ.* 1828) of the habits of Coenobita in Jamaica, in which it is stated that the natives habitually bake the crab in its shell, and the author assures us it is quite a savoury dish thus prepared. It is still eaten largely on that island.

NOTE ON THE STRUCTURE OF THE EYE.

Since this Memoir was put in type, I have seen a recent paper by Dr. E. Trojan on "Das Auge von Palaemon squilla" (Denk. d. Math. Naturwiss. Klasse d. K. Akad. d. Wiss. Wien, Bd. 88, 1912).

The following are the most interesting points in it:—He agrees with Parker that there are only two corneal cells. They are broader distally than proximally, so that they appear triangular in transverse section. The crystalline cells are abruptly cone-shaped distally, and pass between the corneal cells to the facet: he confirms Parker in regard to their general structure.

The general structure of the retinular cells and rhabdome is as Parker and later writers have described, but he supports Hesse's opinion (and differs from Parker and Schneider) that there is no "zwischensubstanz" between the "stiftchen" composing each half-plate of the rhabdome. Three optic ganglia are described.

The most important part of the paper is devoted to a study of the pigment of the eye in darkness and light; this, however, is best consulted in the original. The author states that there are only two pigment-bearing cells, which form a continuous tubular sheath enclosing the whole ommatidium, and believes this to be the case for all Decapods. Parker's statement that the retinular cells and tapetum (accessory) cells are pigmented, is, therefore, possibly erroneous. The paper is illustrated by most beautiful plates.

EXPLANATION OF PLATES.

Reference Letters.

A.

A_1 = First antenna.
$A._1$ *a.* = Articular cavity of first antenna.
A.$_2$ = Second antenna.
$A._2$ *a.* = Articular cavity of second antenna.
ant. a. = Antennary or lateral artery.
ant. p. = Anterior fold of oesophagus.
asc. a. = Ascending arterioles.

B.

bl. = Abdominal bladder or nephrosac.
bl. c. = Ducts between anterior and posterior vesicular mass.
b. m. = Basement membrane.
bp. = Basipodite.

C.

caec. = Abdominal caecum.
car. = Cardiac foregut.
c. hy. = Corneal hypodermis.
cm. = Oesophageal commissures.
cm. ab. = Abdominal commissures.
c. o. = Cardiac ossicle
cor. = Cornea.
cp. = Carpopodite.
cp. v. = Cardiopyloric valve.
cu. = Cuticle.
cx. = Coxopodite.

D.

d. c. = Dorsal coil of vas deferens.
d. liv. = Ducts of liver.
dp. = Dactylopodite.
d. re. = Distal retinular cells.
d. st. a. = Descending sternal artery.

E.

end. = Endopodite.
eg. l. = Epigastric lobe.
ep. = Epimera.
epl. = Endopleurite.
e.s. = Cells lining the endsac.
est. = Endosternite.
ex. = Exopodite.
ex. ap. = External excretory opening.
ex. op. = Aperture of otocyst.

F.

f. c. = Fat cells.
fl. = Flagellum.
fl. m. = Flexor muscles.
fm. c. = Ferment cells.

G.

$g._2$—$g._6$ = Abdominal ganglia.
g. g. = Green gland.
gl. = Rosette gland.
g. t. = Germinal tubule of testis.

H.

hep. a. = Hepatic artery.
h. g. = Hind gut.
hg. ep. = Epithelium of rectum.
hg. m. = Muscles of rectum.
ht. = Heart.

I.

inf. m. a. = Infra muscular branch of segmental artery.
int. = Intestine.
ip. = Ischiopodite.
i. v. = Inferior valve.

L.

lb. = Cells lining labyrinth.
l. liv. = Left lobe of digestive gland.
l. ov. = Blood vessels to left ovary.
l. p. = Lateral fold of oesophagus.
lt. = Lateral teeth.
lu. = Lumen of oesophagus.

M.

md. = Mandible.
md. a. = Artery to mandible.
m. g. = Mid-gut.
mg. caec. = Paired mid-gut (pyloric caeca).
mp. = Meropodite.
mt. = Median tooth.
m.v. = Median valve.
m. v. l. = Median ventral lobe.
mx. a. = Articular cavity of maxillae.
mx.a.′, *a.″*, *a.‴* = Arteries to maxillae.
mxp. = Maxillipede.
mxp.a.′, *a.″*, *a.‴* = Arteries to maxillipedes.
mxp.a. = Articular cavity of maxillipedes.

N.

n. a.$_1$ = Antennulary nerve.
n. a.$_2$ = Antennary nerve.
n. av. = Otic (Static) nerve.
n. fib. = Nerve fibrillae.
n. md. = Mandibular nerve.
n. md. m. = Mandible muscle nerve.
n. m. o. = Optic motor nerve.
n. mx.′, *n. mx.″* = Nerves to maxillae.
n. mxp.′, *mxp.″*, *mxp.‴* = Nerves to maxillipedes.
n. op. = Optic nerve.
n. op. f. = Optic nerve fibres.
n. p.$_1$—*n. p.*$_5$ = Nerves to pereiopods.
n. pl.$_1$—*n. pl.*$_4$ = Nerves to pleopods.
n. po. = Post-oesophageal nerve.
n. r. = Nerve branches on rectum.
n. teg. = Tegumentary nerve.
n. u. = Nerve of uropods.
nu. = Nucleus.

O.

oes. = Oesophagus.
op. a. = Articular cavity for eye.
opth. a. = Ophthalmic or median artery.

P.

p.$_1$ *a.*—*p.*$_5$ *a.* = Arteries to walking legs.
p. g. = Par-oesophageal ganglion.
pg. l. = Paragastric lobe.
plp. = Pleopod.
p. p. = Prepyloric ossicle.
prop. = Propodite.
prot. = Protopodite.
p. re. = Proximal retinular cells.
pt. = Pigment.
ptc. = Pterocardiac ossicle.
py. = Pyloric ossicle.
py. a. = Pyloric ampullae.
pyl. = Pyloric fore-gut.

R.

rb. = Rhabdome.
r. liv. = Right lobe of digestive gland.
r. ov. = Blood vessels to right ovary.

S.

s. abd. = Superior abdominal artery.
s. c. = Sternal canal.
sca. = Scaphognathite.
seg. a. = Segmental artery.
sg. l. = Supragastric lobe.
smp. = Spermatophore.
sptd. = Spermatid.
sptc. = Spermatocyte.
spz. = Spermatozoa.
st. = "Stiftchen."
st. a. = Sternal artery.
stb$_1$ = "Stiftchen" bundles cut longitudinally.
stb$_2$ = "Stiftchen" bundles cut transversely.
st. bd. = Striated border.
st. g. = Stomatogastric ganglion.
st. n. = Stomatogastric nerve.
s. v. = Superior valve.

T.

T. = Telson.
tes. = Testes.
t. ex. ad. = Tendon of ext. add. mus. of mandible.
T. som. = Thoracic somite.
ts. t. = Glandular tube of testis.

U.

uc. = Urocardiac ossicle.
ur. = Uropod.
ur. an. = "Anlagen" of uropods.

V.

v. d. = Vas deferens.
vit. = Vitrellae or cone cells.

Y.

y. c. = Young cell of digestive gland.

Z.

z. c. = Zygocardiac ossicle.

Roman numerals indicate thoracic somites in several figures.

Plate I.

Fig. A. *Eupagurus bernhardus* (male), viewed from the dorsal side. Natural size.

Fig. B. *E. bernhardus* (female), from the ventral side. The distal joints of the thoracic limbs have been removed and the mouth parts are not shown. The distortion of the sternal plates caused by the asymmetrical chelipedes can be seen. Natural size.

Fig. C. *E. bernhardus.* General view of the animal sitting in its usual posture in a shell of *Buccinum undatum.* Natural size.

Plate II.

Fig. 1. Left first antenna (antennule) from side. × 3.
Fig. 2. Left second antenna, from above. × 3.
Fig. 3. Left mandible, from below. × 4.
Fig. 4. Left first maxilla, from below. × 4.
Fig. 5. Left second maxilla and scaphognathite, from below. × 3.
Fig. 6. Left first maxillipede, from below. × 4.
Fig. 7. Left second maxillipede, from inner side. × 3.
Fig. 8. Left third maxillipede, from inner side. × 2·5.
Fig. 9. Dorsal side of right chela. × $\frac{4}{5}$.
Fig. 10. Left chela, from dorsal side. × $\frac{4}{5}$.
Fig. 11. Left third pereiopod, from front. × 1.
Fig. 12. Left fourth pereiopod, dorsal. × $2\frac{1}{4}$.
Fig. 13. Left fifth pereiopod, dorsal. × $1\frac{1}{4}$.
Fig. 14. First pleopod of female, dorsal. × $3\frac{1}{2}$.
Fig. 15. First pleopod of male, dorsal. × 4.
Fig. 16. Telson, uropods and last abdominal segment. × 3.

PLATE III.

Fig. 17. Endophragmal system from the dorsal side. The carapace and tergum of the last thoracic somite have been removed and the soft parts cleared away. × $1\frac{1}{4}$.

Fig. 18. Endophragmal system. The plates in the fifth somite viewed from behind. × 2.

Fig. 19. Alimentary canal. Longitudinal section through stomach to show the skeletal structures. × $3\frac{1}{2}$.

Fig. 20. Diagrammatic trans. sect. of oesophagus to show glands and constricted lumen

Fig. 21. The stomach from the left side with the organs opening into it. × $2\frac{1}{2}$.

Fig. 22. Transverse section through rectum. × 350.

Fig. 23. Liver tubule in transverse section. × 103.

Fig. 24. "Ferment" cells of liver. × 556.

Fig. 25. Dissection from dorsal surface. The blood system of the dorsal side in front of the heart is shown. Vessels behind the heart have been removed. The left mid-gut caecum has been exposed and spread out. The lobes of the digestive gland have been separated to show the alimentary canal, and the left lobe has been turned over to show the testis imbedded in it. × $1\frac{1}{2}$.

PLATE IV.

Fig. 26. The sternal artery and its branches from the dorsal side. The descending portion of the artery is turned to the right side. The vessels to the pereiopods have been cut short. × $1\frac{1}{2}$.

Fig. 27. Arterial system of the abdomen. The vessel *s. Abd.* runs on the surface of the liver, the vessel *seg. a.* underneath on the muscle.

Fig. 28. Heart, latero-dorsal view. × 6.

Fig. 29. Excretory system. The left epigastric lobe, all the other organs of body, the muscles and the abdomen have been removed. Semidiagrammatic. × 2.

Fig. 30. Second antenna from below to show the excretory orifice. × 3.

Fig. 31. Excretory system. Section of wall of nephrosac. × 290.

Fig. 32. Section of portion of antennary gland to show the cells of the endsac and labyrinth. × 180.

Fig. 33. The Eye. Longitudinal section (semi-diagrammatic) of an ommatidium, very greatly magnified (modified after Hesse and Schneider).

Fig. 34. The Eye. Diagram of a proximal retinular cell (modified after Parker).

Fig. 35. The left auditory sac (statocyst) with the surrounding tissues removed. The sac has been cut open from the dorsal surface to expose the sensory region. × ca. 23.

Fig. 36. Plumose seta from the statocyst, very greatly magnified.

PLATE V.

Fig. 37. Nervous system of the cephalothorax from above. The nerves have been cut short before they enter the appendages. × ca. $1\frac{1}{2}$.

Fig. 38. Nervous system. The abdominal ganglia and their connective and branches. × 2.

Fig. 39. The front of the stomach with the stomatogastric system of nerves. × 4.

Fig. 40. The right testis from above, with the vas deferens. × 2.

Fig. 41. Testis. A tubule in the region of the "dorsal coil" opened from the side. The chitinous tube of spermatozoa is seen to be partially divided up. × ca. 25.

Fig. 42. Testis. Spermatophores lower down the tube than in fig. 41. × ca. 50.

Fig. 43. A complete spermatophore at the end of the vas deferens, with a portion of its ribbon. × 123.

Fig. 44 (*a* and *b*). Spermatozoids, (*a*) from the side, (*b*) (after Retzius) from above.

Fig. 45. Section through glandular portion of testis. × 103.

Fig. 46. Section through germinal tubules containing free spermatozoa. × 103.

PLATE VI.

Fig. 47. Fourth zoea of *Eupagurus bernhardus*, from the right side. × 16.

Fig. 48. Telson of first zoea of *E. bernhardus*. × 25.

Fig. 49. Telson of first zoea of *E. prideauxii*. × 25.

Fig. 50. Chela of fourth zoea of *E. bernhardus*. × 35.

Fig. 51. Telson of second zoea of *E. bernhardus*, with "anlagen" of uropods. × 14.

Fig. 52. Tip of uropod of fourth zoea.

Fig. 53. Uropod of third zoea.

Fig. 54. First maxillipede of fourth zoea. × 50.

Fig. 55. Telson and uropods of fourth zoea. × 28.

Fig. 56. First maxillipede of first zoea. × 60.

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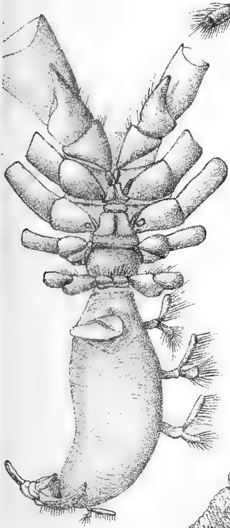

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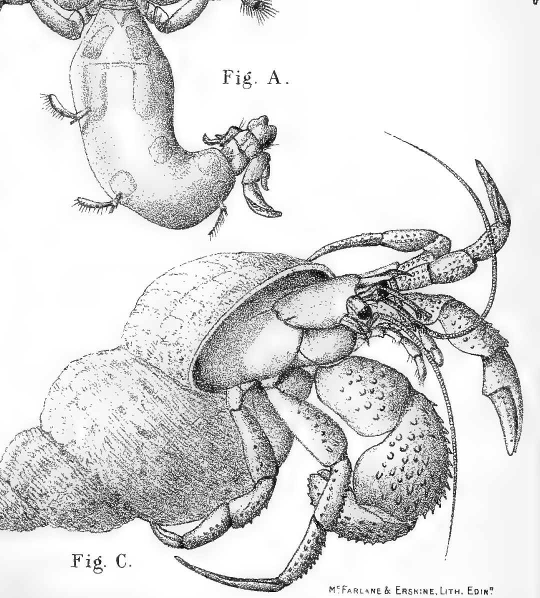

Fig. C.

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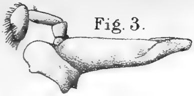
EUPAGURUS.


Fig. 1.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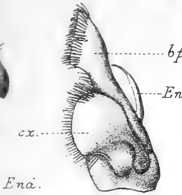

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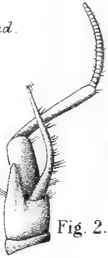
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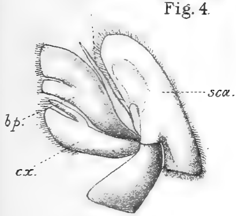

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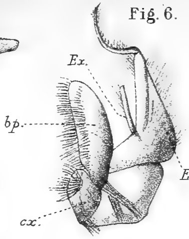

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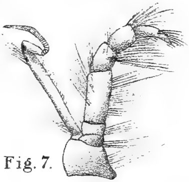
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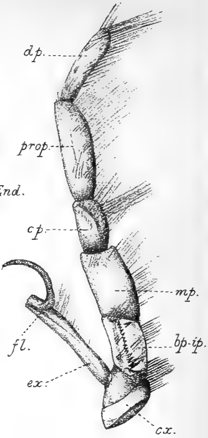

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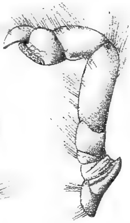
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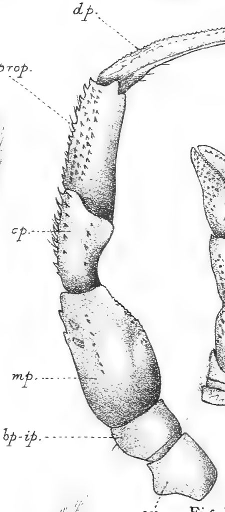

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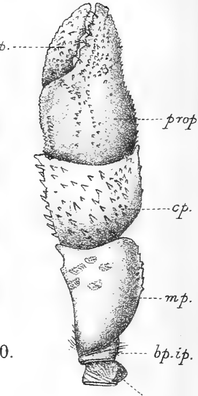

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Fig. 13.


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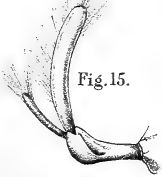
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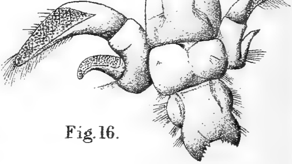
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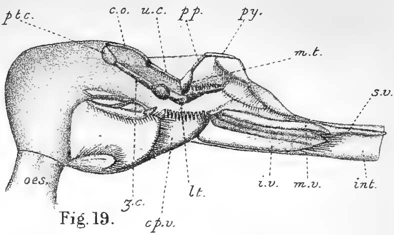
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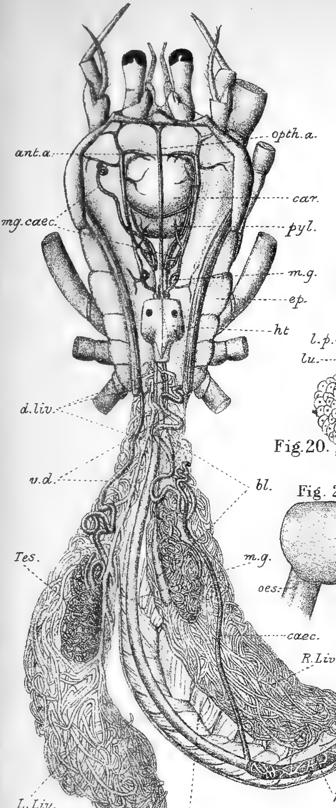
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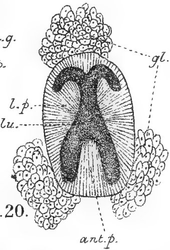
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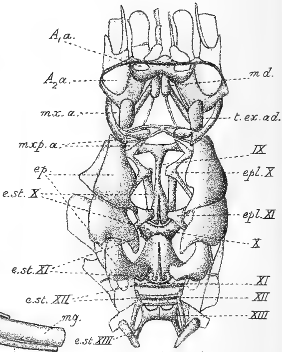
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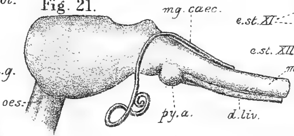
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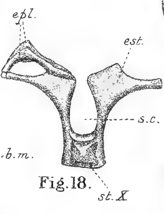
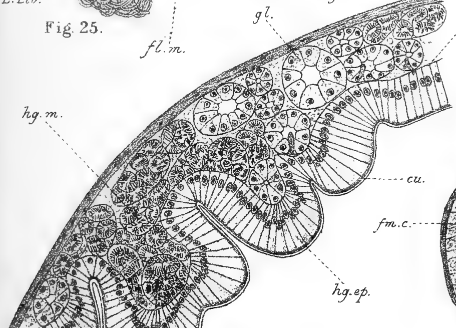


Fig. 18.


Fig. 24.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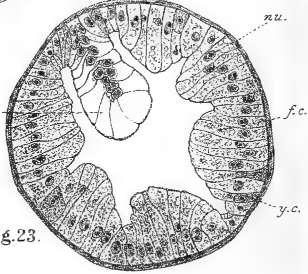
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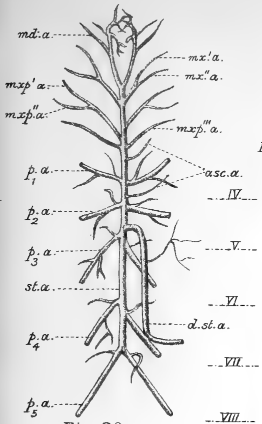

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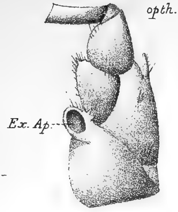

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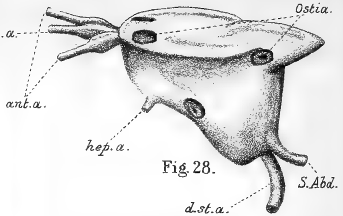
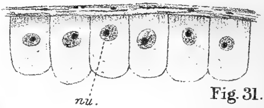


Fig. 28.



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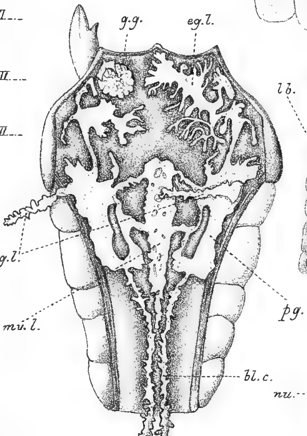

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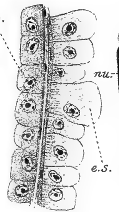

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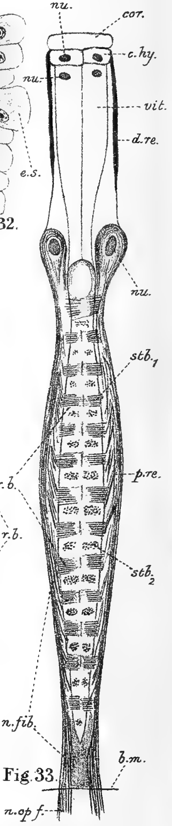

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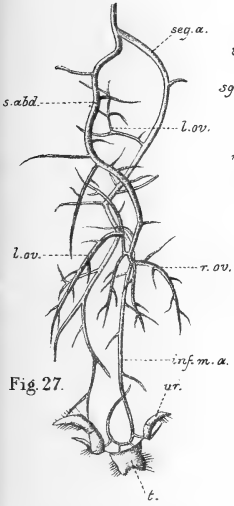

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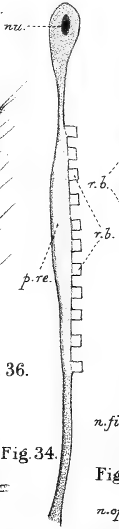

Fig. 34.

Fig. 36.

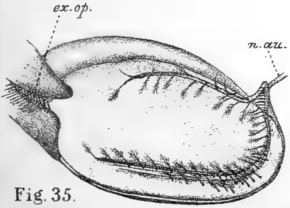

Fig. 35.

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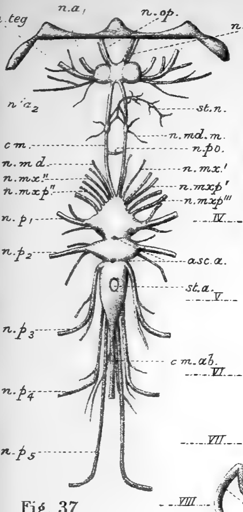

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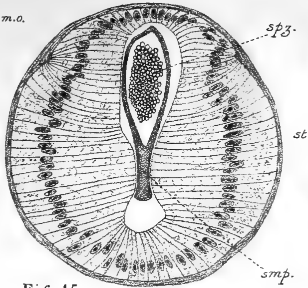

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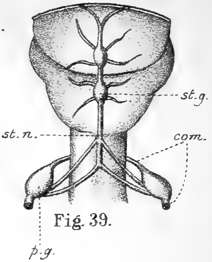

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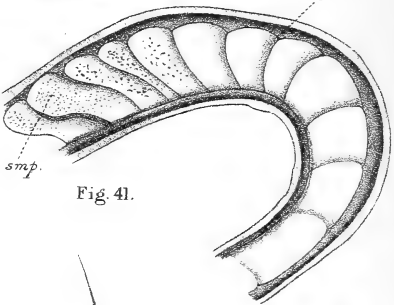
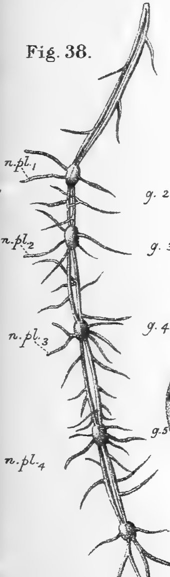


Fig. 41.

Fig. 40.



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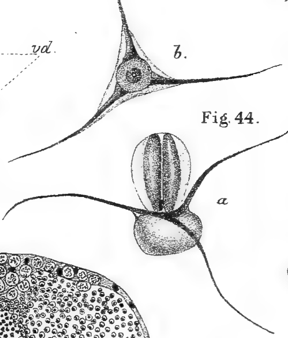

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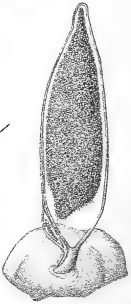

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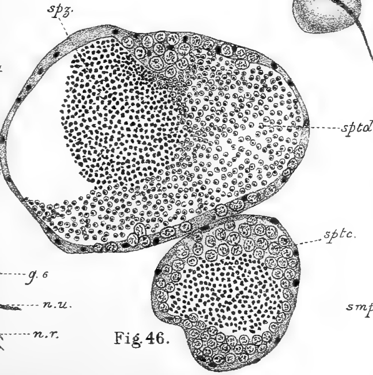

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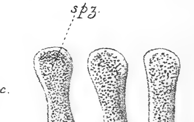

Fig. 42.

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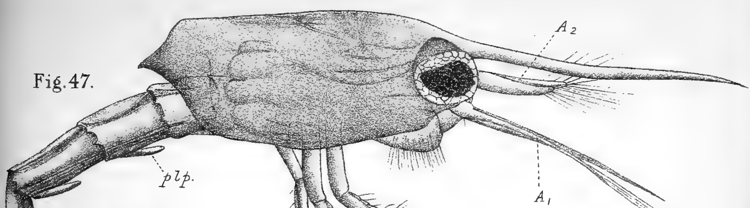
Fig. 47.



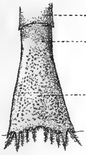
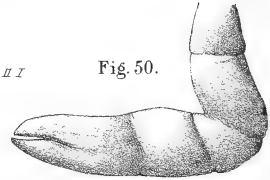
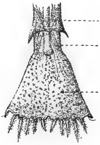


Fig. 48.

Fig. 50.





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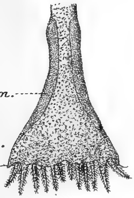
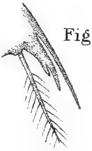


Fig. 51.

Fig. 53.



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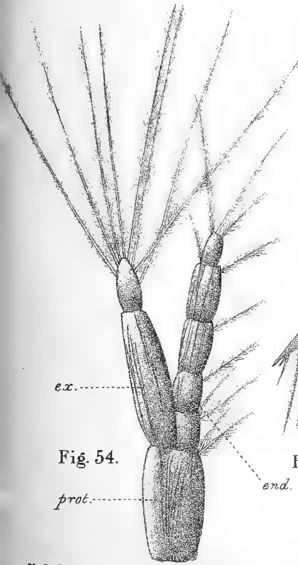

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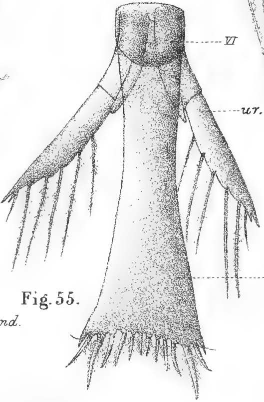

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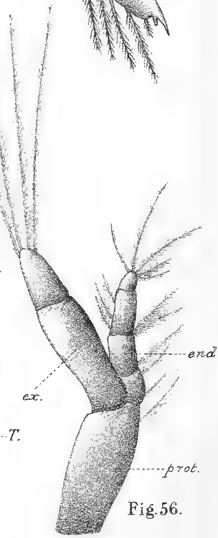

Fig. 56.

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