PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXXI.

SESSION 1916-1917.

LIVERPOOL:

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1917.

CONTENTS.

I.—Proceedings.

	PAGE
Office-bearers and Council, 1916-1917	vii
Report of the Council	viii
Summary of Proceedings at the Meetings	ix
List of Members	xii
Treasurer's Balance Sheet	xvi

II.—Transactions.

Presidential Address—"The Economy of Movement." By Prof. J. S. Macdonald, B.A., F.R.S. . . . 3

Thirtieth Annual Report of the Liverpool Marine Biology Committee and their Biological Station at Port Erin. (With an Address upon "Sir Wyville Thomson and the 'Challenger' Expedition.") By Prof. W. A. Herdman, D.Sc., F.R.S. 15

Report on the Investigations carried on during 1916, in connection with the Lancashire Sea-Fisheries Laboratory, at the University of Liverpool, and the Sea-Fish Hatchery at Piel, near Barrow. By Prof. W. A. Herdman, D.Sc., F.R.S., Andrew Scott, A.L.S., and James Johnstone, D.Sc. . 77

PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents:

1886—1887 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—1888 J. J. DRYSDALE, M.D.
1888—1889 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—1890 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—1891 T. J. MOORE, C.M.Z.S.
1891—1892 T. J. MOORE, C.M.Z.S.
1892—1893 ALFRED O. WALKER, J.P., F.L.S.
1893—1894 JOHN NEWTON, M.R.C.S.
1894—1895 Prof. F. GOTCH, M.A., F.R.S.
1895—1896 Prof. R. J. HARVEY GIBSON, M.A.
1896—1897 HENRY O. FORBES, LL.D., F.Z.S.
1897—1898 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—1899 Prof. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
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.
1912—1913 JAMES JOHNSTONE, D.Sc.
1913—1914 C. J. MACALISTER, M.D., F.R.C.P.
1914—1915 Prof. J. W. W. STEPHENS, M.D., D.P.H.
1915—1916 Prof. ERNEST GLYNN, M.A., M.D.

SESSION XXXI, 1916-1917.

President:

Prof. J. S. MACDONALD, B.A., F.R.S.

Vice-Presidents:

Prof. ERNEST GLYNN, M.A., M.D.
Prof. W. A. HERDMAN, D.Sc., F.R.S.

Hon. Treasurer:

W. J. HALLS.

Hon. Librarian:

MAY ALLEN, B.A.

Hon. Secretary:

JOSEPH A. CLUBB, D.Sc.

Council:

R. BAMBER, M.Sc. (Miss).
J. W. CUTMORE.
G. ELLISON.
W. T. HAYDON, F.L.S.
J. R. HOBHOUSE.
J. JOHNSTONE, D.Sc.
DOUGLAS LAURIE, M.A.
W. S. LAVEROCK, M.A., B.Sc.
C. J. MACALISTER, M.D.
WM. RIDDELL, M.A.
Prof. J. W. W. STEPHENS, M.D.
W. RIMMER TEARE.

Representative of Students' Section:

Miss H. M. DUVALL, B.Sc.

REPORT of the COUNCIL.

DURING the Session 1916-17 there have been seven ordinary meetings and one meeting in the form of a visit to the Liverpool Public Museum.

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

On the invitation of the Council, Mr. Arnold T. Watson, F.L.S., of Sheffield, lectured to the Society at the March Meeting, on "The Methods and Habits of Tube-building Worms."

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	48
Associate members	14
Student members, including Students' Section, about	30
Total	92

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the thirty-first session was held at the University, on Friday, October 13th, 1916.

The President-elect (Prof. J. S. Macdonald, B.A., F.R.S.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1915-1916 (see "Proceedings," Vol. XXX, p. viii) was submitted and adopted.
2. The Treasurer's Balance Sheet for the Session 1915-1916 (see "Proceedings," Vol. XXX, p. xvi) 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 Prof. Ernest Glynn, M.A., M.D. ; Hon. Treasurer, W. J. Halls ; Hon. Librarian, May Allen, B.A. ; Hon. Secretary, Joseph A. Clubb, D.Sc. ; Council, R. Bamber, M.Sc. (Miss), J. W. Cutmore, G. Ellison, W. T. Haydon, F.L.S., J. R. Hobhouse, J. Johnstone, D.Sc., Douglas Laurie, M.A., W. S. Laverock, M.A., B.Sc., C. J. Macalister, M.D., F.R.C.P., W. Riddell, M.A., Prof. J. W. W. Stephens, M.D., and W. Rimmer Teare.
4. Prof. J. S. Macdonald, B.A., F.R.S., delivered the Presidential Address on "The Economy of Movement" (see "Transactions," p. 3). A vote of thanks proposed by Prof. Ramsden, seconded by Prof. Herdman was passed.

The second meeting of the thirty-first session was held at the University, on Friday, November 10th, 1916. The President in the chair.

1. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee, and gave an address on the "Life and Work of Sir Wyville Thomson, the great organiser of the 'Challenger' Expedition" (see "Transactions," p. 31).

The third meeting of the thirty-first session was held at the University, on Friday, December 8th, 1916. The President in the Chair.

1. Prof. Herdman, F.R.S., in continuation of his lecture on "Sir Wyville Thomson" gave a valuable epitome of the chief scientific results of the "Challenger" Expedition (see "Transactions, p. 31).

The fourth meeting of the thirty-first session was held at the University, on Friday, January 12th, 1917. The President in the chair.

1. Mr. G. Ellison submitted a note on the points of difference between the Willow Warbler and Chiff Chaff.
2. Mr. J. W. Cutmore gave an address on "Observations on Bird Life in the Neighbourhood."
3. Dr. Johnstone described and exhibited some Oceanographic Apparatus.

The fifth meeting of the thirty-first session was held at the University, on Friday, February 9th, 1917, jointly with the Students' Society. The President of the Students' Section (Miss H. M. Duvall, B.Sc.) in the chair.

1. Addresses were delivered on "Animal Parasites and Disease in War Time," by Miss Mackinnon, D.Sc., and Messrs. Williamson and Malins Smith.

The sixth meeting of the thirty-first session was held at the University, on Friday, March 9th, 1917. The President in the chair.

1. On the invitation of Council, Mr. Arnold Watson, F.L.S., lectured on "The Methods and Habits of Tube-building Worms." This lecture was of great interest, containing an account of Mr. Watson's observations of the varied methods of tube-building of a number of species of Annelids. Many original lantern slides were used in illustration, and the cordial thanks of the meeting were accorded to the lecturer.

The seventh meeting of the thirty-first session was held at the University, on Friday, May 11th, 1917. The President in the chair.

1. The President (Prof. Macdonald, F.R.S.) in continuation of the subject of the Presidential Address gave a lecture on "The Cost of Walking" (see "Transactions," p. 3).

The eighth meeting of the thirty-first session usually held as a Field Meeting, took place in a visit to the Liverpool Public Museum, on Saturday, June 16th. The Curator (Dr. Clubb) conducted the party round the Museum Galleries, after which a meeting was held in the Study Collection Gallery. The President took the chair and demonstrations were given by Mr. J. W. Cutmore on "Field Collectors' Methods with Birds and Mammals," and by Mr. W. S. Laverock, B.Sc. on "Botanical Collecting." At the short business meeting, on the motion of Prof. Macdonald, F.R.S., seconded by Mr. W. J. Halls, Dr. J. A. Clubb was elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1916-1917.

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.

1913 Beattie, Prof. J. M., M.A., M.D., The University, Liverpool.

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.

1917 Duvall, Miss H. M., B.Sc., Zoology Department, University, Liverpool.

1910 Ellison, George, 52, Serpentine Road, Wallasey.

1902 Glynn, Dr. Ernest, Vice-President, 67, Rodney Street.

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, 48, 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., Dowsefield, Allerton.
1903 Holt, Richard D., M.P., 1, India Buildings, Liverpool.
1912 Jackson, H. G., M.Sc., Zoology Department, University, Birmingham.
1898 Johnstone, James, D.Sc., 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 Macalister, C. J., M.D., F.R.C.P., 35, Rodney Street, Liverpool.
1915 Macdonald, Prof. J. S., B.A., F.R.S., PRESIDENT, The University, Liverpool.
1917 Milton, J. H., F.G.S., Merchant Taylors School, Great Crosby.
1913 Mottram, V. H., Physiological Department, University, Liverpool.
1904 Newstead, Prof. R., M.Sc., F.R.S., University, Liverpool.
1904 O'Connell, Dr. J. H., 38, Heathfield Road, Liverpool.
1913 Pallis, Mark, Tätoi, Aigburth Drive, Liverpool.
1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.
1915 Prof. W. Ramsden, University, 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.
1886 Smith, Andrew T., 21, Croxteth Road, Liverpool.
1903 Stapledon, W. C., "Annery," Caldy, West Kirby.

1913 Stephens, Prof. J. W. W., M.D., University, Liverpool.
1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.
1905 Thompson, Edwin, 25, Sefton Drive, 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.

1916 Atkin, Miss D., 16, Alexandra Drive, Liverpool.
1915 Bamber, Miss, M.Sc., Zoology Department, The University, Liverpool.
1905 Carstairs, Miss, 39, Lilley Road, Fairfield.
1914 Cutmore, J. W., Free Public Museum, Liverpool.
1916 Gleave, Miss E. L., M.Sc., Zoology Department, University, Liverpool.
1913 Hamilton, Erik, M.Sc., 96, Huskisson Street, Liverpool.
1905 Harrison, Oulton, 18, Limedale Road, Mossley Hill.
1916 Horsman, Miss Elsie, B.Sc., 17, Hereford Road, Wavertree.
1910 Kelley, Miss A. M., 10, Percy Street, Liverpool.
1912 Lyon, Miss Una, High School for Girls, Aigburth Vale, Liverpool.
1912 Parkin, Miss A. B., 3, Cairns Street, Liverpool.
1915 Stafford, Miss C. M. P., B.Sc., 312, Hawthorne Road, Bootle.
1903 Tattersall, W., D.Sc., The Museum, Manchester.
1915 Teare, W. Rimmer, 12, Bentley Road, Birkenhead.

C. University Students' Section.

President: Miss H. M. Duvall, B.Sc.

Secretary: Miss Laura Davies.

(Contains about 30 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.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr. IN ACCOUNT WITH W. J. HALLS, HON. TREASURER. **Cr.**

1916, Oct. 1st to Sept. 30th, 1917.	£	s.	d.
To Teas	1	4	3
,, Fire Insurance—Society's Library	2	4	0
,, Messrs. Tinling & Co.	28	14	4
,, Hon. Secretary's Expenses	2	1	0
,, Hon. Librarian's Expenses	2	8	9
,, Cash in Librarian's hands	1	0	0
,, Balance in Bank	2	6	10
,, Cash in hand	11	10	9
	£51	9	11

INVESTMENT:—

	£	s.	d.
£125 4 % Debenture Stock (Commercial Cable Co.) at £70	£87	10	0

1916, Oct. 1st to Sept. 30th, 1917.	£	s.	d.
By Balance from last Account	6	11	11
,, Subscriptions:—			
Members	15	15	0
,, (Arrears)	2	2	0
,, (Advance)	1	1	0
Associates	3	3	0
,, Sale of Volumes	16	16	9
,, Sale of Volumes (last Session)	2	1	6
,, Interest on Investment	3	15	0
,, Bank Interest	0	3	9
	£51	9	11

LIVERPOOL, *September 30th, 1917.*

Audited and found correct,

JAS. JOHNSTONE,

October 8th, 1917.

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

PRESIDENTIAL ADDRESS

ON

THE ECONOMY OF MOVEMENT

By Professor J. S. MACDONALD, B.A., F.R.S.

[Delivered, October 16th, 1916.]

As no doubt is usual, but none the less necessary, I should like to express my pleasure in appearing for one year as the President of this Society, which has now for long been known as one of the most energetic centres of work and interest in Biological Science. The encouragement it supplies travels much further than to Liverpool and the immediate district. In Sheffield, for example, I have frequently heard my friend Mr. Arnold Watson, and others, express gratitude for stout support, both from the Society and from Professor Herdman, who perhaps will pardon me when he finds himself described as the vertebral column of this Society. Indeed, I would like very much to be allowed to say how much I am, personally, indebted to Professor Herdman. It will be accepted as true that an investigation of economy is not without expense, and considerable expense, and there have been times when, pursuing such an investigation, I have had to encounter and deal with such expenses that friendly support was of the utmost value. In such circumstances I am proud to say I have received most valuable support from Professor Herdman, and that, indeed, without, at the time, being aware of it. If the whole of the membership of this Society is similarly united to its backbone, then there is here a unity of a remarkable kind, which should not escape mention.

And now to deal with the "Economy of Movement." What I would like to do, would be to explain how anyone possessed of a certain length of limb, and a certain body-weight and weight of limb, should best set about the performance of movement so that the largest amount of movement might be performed at the least possible expense. What one can actually do is something very far short of this, but still perhaps sufficient to indicate that systematic knowledge of the kind required is not out of reach. I am, for instance, only able to talk about two kinds of movement; having to exhibit on the one hand some information gained from a study of the expense of cycling, performed as on the ordinary "push-cycle," except in so far that the resistance encountered was not that of the wind and road, but that of a "brake," which could be applied to any required degree and maintained in uniform action; and on the other hand having also something to say about the expense of walking, in this case against so little resistance as is encountered "on the grass at Oxford" (Douglas and Haldane).

Now, perhaps, not true of walking, but certainly in the case of cycling (under the conditions examined) there is no difficulty in measuring all the external work done. This obtained value may then very readily be arranged on one side of a balance sheet, and on the other side it is possible, as will be briefly explained, to state the total expense incurred in gaining this value. However, this statement would not be a really useful return of gain and loss, and obviously so since it is clear that the process of "cycling" would be even still more advantageous if the external work done was reduced to a negligible quantity—although then, according to the method of arranging the account as described, there would seem to be no value gained—since movement would then be facilitated and proportionately a greater distance covered, a greater amount of locomotion secured. That is to say, that in addition to the external work performed on masses external to the worker, there is also to be considered the work done upon his own limbs and body, and the value obtained in their motion. However, this latter tale of work is at the present time not capable of exact expression as so many units of work, so many foot-pounds or kilogrammemeters, or as so many comparable units of other forms of energy, for example, as so many units of heat, or calories. That this must, unfortunately, be the case one realises at once from the fact that we are not yet sufficiently acquainted with the exact mode of motion of the constituent masses of the body and limbs to make out the statement of movement in an exact algebraical fashion. It is impossible, then, to go further in this direction than to say that such and such movements were performed with such and such rates of repetition. Thus the credit side of the balance-sheet contains two fractions, one being a statement of this kind with regard to the movements made, and the other a more exact statement of the external work in definite measured units of energy per unit of time.

With regard to the debit side of the balance-sheet, the "cost" incurred—and necessarily almost simultaneously paid—there is no such complication, since both "movement" and external work are paid for in exactly similar coin. It has been shown by painstaking and elaborate scientific effort that no payment is made for either in other coin than unit of oxidation. Expense then is always expressible either in terms of fuel utilised, or oxygen absorbed, or products of oxidation emitted. It is obvious, of course, that each kind of fuel will provide somewhat different sums of energy, but there are not many kinds of fuel available in the body, and it is possible, by an adequate, but quite simple, examination of the products of oxidation emitted, to recognise just what kind of fuel is being utilised at each moment dealt with. Indeed, it is possible to do this without further data than the amount of carbon-dioxide emitted and oxygen absorbed. The ratio between these two quantities is known as the "respiratory quotient," and from this "respiratory quotient" it is now possible, as the result of fundamental experiment, to distinguish the kind of fuel utilised, and to assess the energy liberated by its oxidation. Thus, if the amount of oxygen absorbed per unit time, and the value of the "respiratory quotient" are known, it is possible to state exactly the payment then being made in terms of energy. Such a statement takes the form that at the time so many calories are being liberated per unit of time, usually, therefore, so many "calories per second."

Several methods have been devised to collect the underlying necessary data during the performance of movement and work; none more convenient than that of Haldane and his collaborators, which has the genius to be almost ridiculously simple, and which has been shown to be sufficient. The subject inflates a gas-bag with his expired air, without encountering any but the most negligible resistance when doing so. He carries the gas-bag on his back, and can commence and desist from inflating this bag when he likes, and through a known time, as measured by a stop-watch. This air is then analysed in conveniently simplified apparatus designed exactly for the purpose, and the account of expense at once rendered.

Now, this simple means of rendering the account is entitled to full confidence, because of the experimental labours of those who have used far more elaborate and intrinsically more complete methods. I can show you diagrams and introduce the method of the "respiration-calorimeter" of Atwater, and later of Atwater and Benedict, by which it is possible to obtain separate statements of the data of respiration on the one hand, and of the data of "heat-production" or of liberation of energy on the other. However, it will be as well not to occupy too much of your attention with the details of such complicated apparatus. On these more complicated efforts, such as those of the American scientists mentioned and also of German and Swedish scientists, rests the foundation from which simplified effort is possible. In my own experiments this more simplified effort took the form of dealing only with the tale of liberated energy, using the calorimetric side of Atwater and Benedict's respiration calorimeter. As compared with the collection of "respiration data" this alternative method offers the advantage of greater self-sufficiency, but it is far the more elaborate, and because of its elaboration far the less elastic and less readily adaptable to the study of expenses incurred in different kinds of movement, so that one has been tied down to the repetition of a certain smaller group of experiments. This is a fact, however, not without advantage.

I have dealt, then, with the general form of the two statements, such as may be encountered on any of these "balance-sheets," of value obtained and expenses paid. On the one side so much, and such, movement, and so much external work performed, the latter expressed perhaps most usually as so many calories per second; and on the other side so many units of energy liberated, also expressed—since as a matter of fact thus measured—as so many calories per second. However, I should say at once that I have represented the procedure adopted somewhat too simply. It is the procedure which I have myself adopted, but not then in agreement with general usage, and in dealing with it it has been necessary to show that the results expressed in this way had a concordance not otherwise demonstrable. I shall not, however, complicate this explanation by too expansive an allusion to this concordance, or to the evident discord maintained by the more usual mode of procedure. The point is this. It is usual to assume that there is a condition known as "rest" which may occupy the whole scene in resting moments, but which also is maintained beneath the phenomena of movement and work. Thus, when the expense of movement is usually presented it is the habit to deduct a certain allowance for the co-existent state of "rest" and all sorts of elaborate estimates are made as to the nature of this allowance, some preferring the degree of expense which is found during "sleep," some that of "sitting," or of "lying down." There is naturally reason behind this quaint method, since it is reasonably advanced that some of the expensive processes of the body have none of that immediate association with work which would make them entirely proportionate to the latter. However, I have abandoned this suggestion and interested myself in a point of view derived, in its essence, from my predecessor as Professor of Physiology, here, Professor Sherrington. Of the prestige obtainable by utilising his name in this place specially, but as a matter of fact similarly in any place where Biologists are met together, I am fully aware, and I do not intend to press it unduly in relation to a statement which stands on its own foundation. According to my examination of these accounts, there is no "rest" in movement, and no allowance is made for it. According to Sherrington, "rest" is, in a sense, a movement, which is replaceable therefore completely by other, different, movements. I need not then allude again to the fact that no subtraction is made in any of my accounts for phenomena of any kind, such as is usually done in writing off the debit due to rest, and that it is really the case that movement and work are balanced against total temporary expense.

I am afraid that there are other points in which I can make no claim for orthodoxy. They are not of the same essential importance since not affecting the mode of stating the accounts, but are perhaps worth some brief allusion. You will not find, for example, any attention paid to characteristics of the subjects of my experiments other than their body-weight. It is true that I would like to pay attention to the lengths of their limbs, but have failed to do so adequately, that is to say, to such a degree as to place direct measurements of length in certain positions now occupied by statements of body-weight, with which after all these lengths, in the average, vary. Nothing is said as to age, diet, habit and other matters to which prominence is usually given—and that not without thought, but because the supposed necessity for dealing with these points has never arisen. In my earlier experiments subjects were chosen who differed from one another in certain directions very remarkably. Comparing in them the results, on the one hand of habits which made for social eminence, and on the other for complete failure, I found no distinctions with regard to the price paid for movement and work, that were not concordantly explainable as proportionate to differences in body-weight. Therefore, when extending my list of subjects it was extended as far as possible along the scale of available body-weights, and not along the scale of habits. Now, it is not orthodox to regard these other characteristics as producing so little influence on the price of movement and work actually accomplished. Nevertheless, this opinion is the definite result of some experience leading to the different view that these habits tend rather to operate upon the effective accomplishment of movement than upon the expense of such movement when definitely accomplished. Be this as it may be, the results obtained are such as to confirm immediately the major importance of body-weight.

This importance of body-weight can be shewn as convincingly in reference to the maintenance of rhythmical movement, as in reference to external work performed by movement. It is curious, however, and not hitherto expected, that the two processes are oppositely affected, movement being hampered and the performance of external work facilitated by increasing body-weight. The fact was brought to my notice in the following fashion. In a long series of experiments with subjects cycling against the resistance of a variable "brake," the rate of "cycling" was carefully maintained the same throughout the series, all sorts of precautions being observed to secure that end. Relieved then from the necessity for considering any other than one particular rate of similar movement, I was in a good position to observe the consequences of altering the value of the "brake." It might be said, perhaps, that when the "brake" was altered, so that a different amount of external work was performed, it might be possible that the character of the movement would also be to some degree affected. This is probably true enough when extreme changes are made, such as on the one hand complete removal of the "brake," and on the other its insertion to such values as almost to render continuance of the experiments impossible. These extremes were, however, avoided, and with the variations of "brake" chosen no modification in the character of movement was discernible. Now, it was interesting, and quite unexpected, to discover when the results of the whole series of experiments were tabulated and analysed that the variation in total expense with the body-weight regularly diminished as the value of the "brake" was increased, until at a certain value of the "brake" there were no such differences, and every cyclist paid the same price no matter what his weight. It was still more interesting to discover later that this regular modification in the influence of the body-weight was analysable into the statements made just now, that its influence was twofold, and that it affected the performance of movement in an adverse, and the performance of work in a favourable manner. The analysis is such as to point to very exact conclusions in these directions. Thus, the cost of work done on the cycle in these experiments was equal to the value of the work multiplied by the following factor,

$$\frac{64{\cdot}6}{W^{0{\cdot}7}},$$

where "W" is the subject's body-weight. On the other hand the cost of the underlying movement at this particular rate, which was maintained throughout the series was equal to a "constant" multiplied by $W^{1{\cdot}44}$. The logical deduction from this definite analysis of the results obtained is, that had the value of the "brake" been still further increased above that actually utilised, one would have had to deal with "total expenses," including the expenses of movement and work, which would have been found to *diminish* with increasing body-weight. Well, there is nothing in these findings more than confirmation of a generally wide-spread notion, that for mere purposes of movement lightness is a valuable asset, and that for increasing work an increase in the workman's body-weight is similarly valuable. One may conclude that in reference to this particular movement of cycling the search for "economy" must be made with an eye upon the work that is to be accomplished by the movement, up to a certain amount of work lightness is economical, at an intermediate range (work of $\frac{1}{10}$ Horse Power approximately) lightness, or weight, is of no consequence, beyond that weight is economical.

Now, having in this way ascertained the factor by which work had to be multiplied, that is to say, knowing the "efficiency" available, it was possible to remove the cost of work from other statements of the expense of cycling, and that even at any other rate of movement, so long as the amount of the work done upon the "brake" had been measured. One of my subjects had, in the interests of this operation, cycled at rates of many different values along the whole available scale of rate such as he could maintain uniformly for the duration of an experiment. Eliminating from his total expenses the cost of work performance I was able to present the cost of movement at every such rate, and found the effect of rate to be complicated, more complex, for example, than mere proportionate increase with increase of rate, but continuous, so that it could be expressed in a single mathematical formula, modified in each case only by insertion of the particular rate then observed. Now the nature of this variation with rate is such as at once to show that movement is most economically performed in this case, not at the slowest rate of movement, but at a certain intermediate rate. In "cycling" movement, at all events, there is a certain "economical rate" of movement, which may readily be ascertained by experiment, and which, in my opinion, is capable of general statement applicable to every kind of subject. Further, the expense of all other rates of movement may be assessed from the expense of this intermediate "economical rate." Now, if this is true, there is the view that the cost of "cycling," and all similar motion and work, may be laid down in a hard and fast fashion, and that every point with regard to its "economy" is completely ascertainable and expressible in absolute units.

Wishing to develop this view I turned my attention to the expenses of "walking" as recorded by different observers, but mainly, since most suitable for the purpose, to a series of data collected by Douglas and Haldane as to the expense incurred by Douglas when walking "on the grass at Oxford" at different rates of progression. Neglecting the external work performed in this process, and treating the whole expense as "cost of movement" I found that the expenses could be expressed in a formula similar to the one which had served to unite the expenses of cycling movement. The similarity is such as to leave little doubt that the two series of accounts are governed, in the main, by similar considerations and that the "economy" of walking is as capable of complete and exact statement as the "economy" of cycling. In this case as in the other, there is clearly a certain intermediate economical rate. In this case there is, however, more immediate hope of discovering the significance of this particular rate, in fact, there is very little doubt as to the order of this significance, but the explanation of this point necessitates a brief statement as to the process of walking.

In the opinion of the brothers Weber, who exhaustively studied the apparatus of walking, and the process so far as the "technique" of their time allowed, the swinging limb in walking behaves exactly as a pendulum, and the variations in the process evident in different walkers depend upon differences in this pendulum. Important amongst the data which they collected on this subject are data showing the length of the step in walking as dependent upon the speed. Consideration of the process as a "pendular process" anticipates this variation in length of step, which they actually observed in a complete and thoroughly scientific fashion. Now, later observers have brought forward certain important considerations and further observations, some of which are hostile to this, so to speak, "pendular" hypothesis, amongst others Marey, who made brilliant observations with all the advantage of a "technique" supplemented by the developments of instantaneous photography. Marey cites one particular point in his observations with regard to the variation of the length of step as if conclusively hostile to the Webers' opinion, and this particular point has been made much of by everyone who has been influenced, as in fact all have been influenced by the general value of Marey's methods. The point is that at a certain "intermediate rate" of walking the change in the length of step alters from one mode to a new one. There is thus a certain nodal point in Marey's observations, whereas in Webers' opinion there is a very definite nodal rate, the "pendular rate" of the limb.

Now, it has interested me to plot out, and attempt further analysis of the data collected by the Webers, and I have found that they may be arranged on a plan not in any way alluded to by the Webers, most probably never considered by them. I intend to publish the details of this plan in a separate paper, and for present purposes their exact nature is of small interest, the pith of the matter, however, is this, that the Webers' data can be shown to illuminate the point raised into importance by Marey. Thus, Marey was evidently unaware that his observation referred to a particular rate of great interest in these classical data of Webers, of great interest in so far as, in the case of their subject, it actually coincides with his "pendular rate." With the assistance of Mr. A. Wallis I have investigated this variation in step in a number of subjects, and have reasons for saying that the mode of variation is not in all cases the same, although in each case definitely regular modes of variation are obviously present. It is not to be expected, and is not as a matter of fact the case, that the coincidence is the same as in the Webers' data. However, of all cases it seems to be true that the "nodal point" referred to as marking an interesting intermediate rate, is also the mark of a rate bearing one of a few limited simple relations to the "pendular rate."

It seems to be the case, then, that interesting rates of walking are all referable to the "pendular rate" of the limb, and I have no doubt that the "economical rate" has the same reference. There are definite reasons for saying so, but they are, unfortunately, complicated. Perhaps it is sufficient to say that dividing the formula for the expenses of Douglas "when walking on the grass at Oxford," by the formulae which give these variations in step as found in the Webers' data, the result is a general expression for the cost of walking per step taken which has a minimal value, and exhibits, therefore, a point of maximum economy, which coincides with the step taken at the "pendular rate." As I have said, this is probably not true of every case, but it is probably a variant of a more general statement also dependent upon the pendular rate, which is more generally true.

It now remains for me to apologise for the inconclusive nature of my statement, and for the arid character of the series of data* by which it has been reinforced. However, there is one conclusion that perhaps may be drawn, namely, that sufficient has been said to show that the expense of movement is probably always capable of exact, and by no means distant, statement, and that the method of statement is being more or less energetically attempted. I may be pardoned for reiterating my opinion, that Sherrington's revelation of the replacement of one whole movement by another and the consequent view that "rest" is, in essence, a movement, form probably the key to the right system of accounts. Up to the present this accountancy, and a real approach to "economy," have been greatly embarrassed by undue attention to "rest."

* These data are published in the *Proc. Roy. Soc.*, B, Vol. LXXXIX, pp. 394-410.

THE

MARINE BIOLOGICAL STATION AT PORT ERIN

BEING THE

THIRTIETH ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE.

By Professor W. A. Herdman, F.R.S.

In this third year of the Great War, the Committee and our other supporters and readers will, I am sure, understand and approve if the Report again takes a shorter form than usual, and deals with little beyond the record of routine work carried out at the Port Erin Biological Station and elsewhere in the L.M.B.C. District.

The "Station Record" and the "Curator's Report" which follow show that during the Easter vacation and the Spring months, when both students and senior workers frequent our marine laboratory more than at any other time of the year, the numbers, though still greatly reduced in comparison with the few years preceding the war, were greater than in 1915. In 1914 we recorded ninety researchers and students occupying work-places in the laboratory; last year we had only fifteen, the present report shows twenty-one. The number of visitors to the Aquarium is now nearly double what it was in 1915, but is far below the usual numbers for recent years.

In regard to the educational work in the laboratories, the usual Easter vacation course in Marine Biology was carried on during April by members of the staff of the Zoology department of the University of Liverpool. The only other Universities represented were Bedford College, London, and the University of Birmingham.

Work out at sea was wholly prevented, by Admiralty regulations, but collecting expeditions as usual, along the shore at low tide, were arranged in the Easter vacation. During the remainder of the year the Curator and his staff made periodic collections from time to time as occasion offered, and plankton samples were taken across Port Erin Bay with regularity twice in each week throughout the year. Special series of gatherings from the motor boat were also taken almost daily during April, August and September, as part of the work in connection with the scheme of "Intensive Study of the Plankton" which has now been in progress for ten years.

It may be useful to students and others proposing to work at Port Erin that the ground plan of the buildings showing the laboratory and other accommodation should be inserted here (see fig. 1, p. 17).

As on previous occasions, the statistics as to the occupation of the "Tables" during the year will first be given, then will follow the "Curator's Report," and after that, I have considered it appropriate to follow up the account I gave in last report of the great Manx Naturalist, Professor Edward Forbes, by a brief account of that later Oceanographer, Sir Wyville Thomson, and his connection with the celebrated "Challenger" Expedition (see p. 31) for the information of our students and other workers at the laboratory.

Curator's Report.

Mr. Chadwick reports to me as follows on the various departments of the work:—

Station Record.

"Twenty-one workers occupied tables in our laboratories during the past year. This number, compared with that of last year, represents an increase of six; and it is gratifying to record that in spite of the distractions of the war, original research once more takes a distinct place in the record of the year's activities. The Easter vacation work was carried on under the direction of Professor Herdman and with the

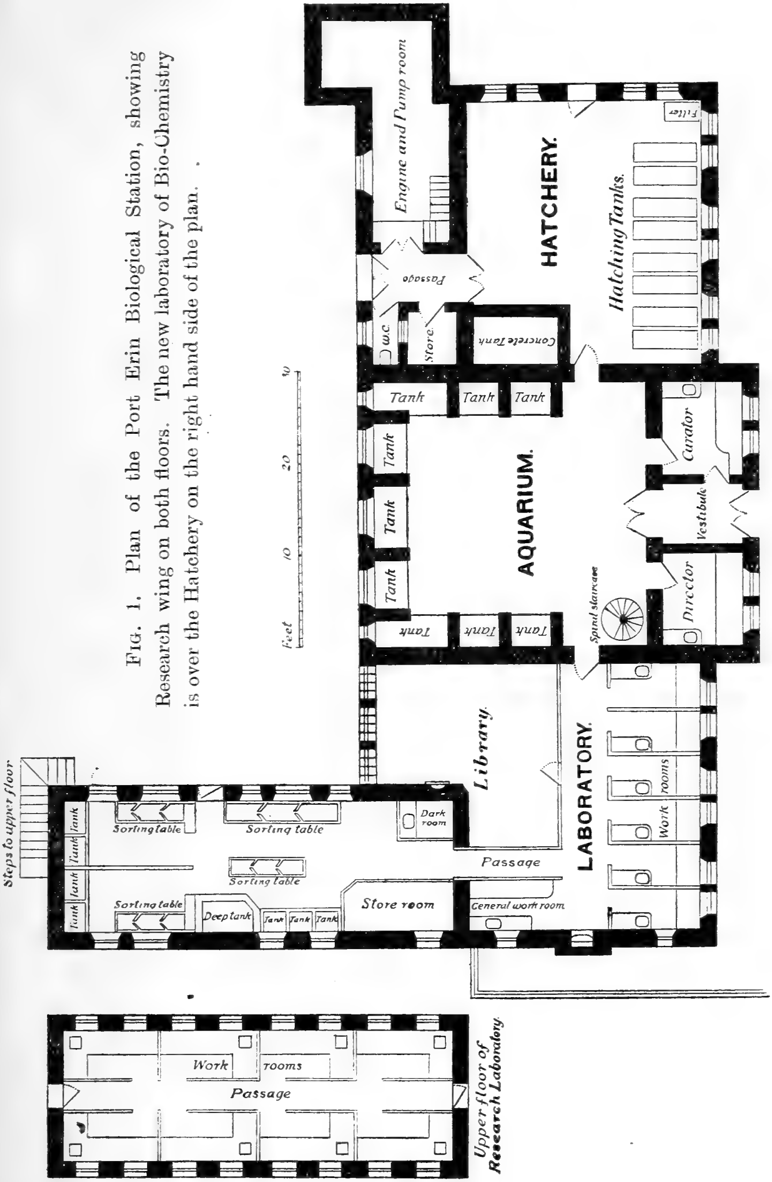


Fig. 1. Plan of the Port Erin Biological Station, showing Research wing on both floors. The new laboratory of Bio-Chemistry is over the Hatchery on the right hand side of the plan.

assistance of Mr. R. D. Laurie and Miss R. C. Bamber, by 15 students, 12 of whom came from the University of Liverpool, 1 from the University of Birmingham, and 2 from the Bedford College for Women, London.

List of Workers.

March 30th to April 14th	Miss G. H. Simpson.—General.
,, ,,	Miss E. D. Cook.—General.
April 1st to 27th.	Professor Herdman.—Plankton.
,, *3rd to 25th.*	Miss R. C. Bamber.—Educational and Research.
,, *4th to 25th.*	Mr. R. D. Laurie.—Educational and Research.
,, *3rd to 18th.*	Miss J. Price.—General
,, *3rd to 8th.*	Miss H. J. Hanly.—General.
,, *3rd to 13th.*	Miss E. V. Creamer.—General.
,, *3rd to 12th.*	Miss B. Jackson.—General.
,, *3rd to 15th.*	Miss G. Andrew.—General.
,, *3rd to 12th.*	Miss E. M. Edge.—General.
,, *3rd to 12th.*	Miss C. Mayne.—General.
,, *3rd to 12th.*	Miss H. Kennedy.—General.
,, *3rd to 13th.*	Miss D. M. Sunderland.—General.
,, *3rd to 13th.*	Miss A. M. Heyes.—General.
,, *3rd to 8th.*	Miss M. H. D. Shacklady.—General.
,, *3rd to 15th.*	Miss L. Davies.—General.
,, *3rd to 15th.*	Miss Selwood.—General.
,, *12th to 28th.*	Miss E. L. Gleave.—Doris.
July 24th to August 3rd.	Mr. R. D. Laurie.—Research.
,, *27th to September 28th.*	Professor Herdman.—Plankton.
August 1st to 29th.	Dr. J. Stuart Thomson.—Alcyonaria.
,, *21st to 29th.*	Miss R. C. Bamber.—Tubularia.
,, *21st to 27th.*	Miss E. L. Gleave.—Doris.

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

Liverpool University Table :—

Professor Herdman.	Miss G. Andrew.	Miss H. Kennedy.
Mr. R. D. Laurie.	Miss H. J. Hanly.	Miss D. M. Sutherland.
Miss R. C. Bamber.	Miss E. V. Creamer.	Miss A. M. Heyes.
Miss E. L. Gleave.	Miss B. Jackson.	Miss M. H. D. Shacklady.
Miss J. Price.	Miss E. M. Edge.	
Miss L. Davies.	Miss C. Mayne.	

Manchester University Table :—

Dr. J. Stuart Thomson.

Birmingham University Table :—

Miss Selwood.

Bedford College for Women, London, Table :—

Miss G. H. Simpson. Miss E. D. Cook.

The Library.

"Our thanks are due to the respective donors for the Annual Reports of the Marine Stations of Millport and Cullercoats, the Fishery Board for Scotland, the Lancashire Sea Fisheries Laboratory; the Journal of the Marine Biological Association; the publications of the National Academy of Sciences, U.S.A., the University of California, the Royal Irish Academy (Clare Id. Survey), and the Colombo Museum; to Mr. H. N. Milligan and Dr. J. F. Gemmill for copies of their papers, and to Mrs. Herdman for the British Association Annual Report.

"The Curator has endeavoured to complete the catalogue of the library, but much remains to be done.

The Fish Hatchery.

"The stock of plaice collected for this year's hatching operations consisted of the survivors of the previous year's stock and 67 fish captured by means of trammel or seine nets in the bay, making a total of 135. This small stock was further reduced by the death of a few of the fish during the winter. Fertilised eggs were first seen in the pond on February 19th, and the hatching apparatus was set in motion two days later, when a small batch of 23,000 eggs were placed in the hatching boxes. The daily numbers of eggs increased considerably during the next few days, over 100,000 being reached on February 28th, ten days earlier than in 1915. Over 900,000 eggs, the maximum daily number for the season, were skimmed from the pond on March 16th, and over half a million were collected on four subsequent dates. The spawners continued to yield good collections of eggs until May 2nd, when only 46,000 eggs and embryos were obtained.

"The Hatchery Record, giving the number of eggs collected and of larval fish set free on the various days, is as follows :—

Eggs collected.		Date.	Larvae set free.		Date.
23,200	...	Feb. 22	11,650	...	March 20
416,850	...	,, 25 to March 4	296,100	...	,, 27
597,450	...	March 6 to 13	594,300	...	April 3
934,500	...	,, 16	555,450	...	,, 10
761,700	...	,, 18 to 23	525,000	...	,, 15
623,700	...	,, 24 to 25	697,200	...	,, 19
1,959,300	...	,, 27 to April 1	1,801,150	...	,, 20
1,253,700	...	April 4 to 6	896,700	...	,, 22
487,200	...	,, 7 and 8	583,800	...	,, 26
695,100	...	,, 11 and 12	625,800	...	,, 29
556,500	...	,, 19 to 21	554,400	...	May 1
516,600	...	,, 24 to 27	520,800	...	,, 6
46,200	...	May 2	35,700	...	,, 11
8,872,000	Total eggs.		7,698,050	Total larvae.	

"The plaice hatching operations were conducted solely by the Assistant Curator, Mr. T. N. Cregeen.

Lobster Culture.

"Owing largely to the want of an efficient boy assistant, it was not found possible to carry on lobster culture on more than experimental lines during the past season. Much of the Curator's time had to be devoted to supervision of the Aquarium ; and though the Assistant Curator devoted a large proportion of his time to cultural work the results do not compare favourably, numerically at least, with those of the past two or three years. Female lobsters with nearly ripe eggs were said to be exceptionally scarce this year, and only 5 were secured. These together yielded 3,857 larvae, 3,300 of which were set free in the first stage, at various points where suitable shelter is afforded ; 347 were transferred to the larger plaice pond, and 200 to one of the smaller tanks in the Aquarium, where they have been under daily observation.

The Assistant Curator has devoted much attention to the question of the most suitable food for the larvae, and finds that the exclusive use of plankton gives the best results. With a coarse tow-net he made almost daily collections of plankton for feeding the larvae in the larger plaice pond and the Aquarium tank. Unfortunately the collection of plankton on a sufficiently large scale is not only laborious but involves the expenditure of much time, as the experience of the past season has shown. Nothing definite can be said with regard to the 347 larvae transferred to the larger plaice pond until the pond is drained and the bottom carefully examined. Of the 200 larvae placed in the Aquarium tank and fed exclusively upon plankton about 20 reached the lobsterling stage. Of 10 larvae placed in a small bell-jar in the Aquarium, for the inspection of visitors, and fed exclusively upon plankton, 6 reached the lobsterling stage.

The Aquarium.

"A very gratifying recovery in the number of visitors to the Aquarium has taken place this year, 3,050—nearly twice last year's number—having paid for admission. The care of the tanks and the maintenance of an attractive exhibition of specimens has again been a matter of much concern to the Staff. A number of plaice hatched this year, and others hatched during the seasons of 1915 and 1914, attracted much attention and excited great surprise at what was almost universally regarded by the visitors as the slow rate of growth of this fish. The lobster larvae, too, excited great interest and prompted many questions with regard to the breeding habits, mode and rate of growth, shell-casting, &c., of the lobster. The practical question 'Why are lobsters so dear?' frequently put by ladies, has afforded the Curator many opportunities of explaining the pernicious effects upon the supply of lobsters of the demand for lobster eggs for making 'coral' sauce.

General.

"Attention has been called from time to time to the obstruction of the flow of sea-water through the galvanised iron pipes which supply the Hatchery and Aquarium, caused by the growth therein of various invertebrates. Three interesting instances of this have occurred during the past year. At the end of December, 1915, owing to a greatly diminished flow of water from the upper storage tank, the supply pipe was disconnected and cleaned. A few inches above its junction with the pipe from the lower storage tank its bore was found to be almost completely obstructed by a large and vigorous colony of the tube-building Polychæte worm, *Salmacina dysteri.* A dense mass of the tiny white calcareous tubes of the worm was cut out of the pipe and placed in a dish of fresh sea-water. Shortly afterwards hundreds of this beautiful little worm were seen fully expanded, and it was noted with interest that though they had grown in the absolute darkness of the interior of the pipe they were deeply tinged with the bright orange-red pigment characteristic of the species. Another tube-building Polychæte worm which has repeatedly obstructed the pipe which supplies the Aquarium tanks is *Sabella pavonia.* In April last a large specimen of this species was taken from the pipe close to the point of attachment of a tap, and was placed by the Curator in one of the shallow table tanks in the Aquarium, close to one side. A stone was placed upon the tapering, closed end of the tube, hereafter to be called the proximal end, to keep it in place. The position chosen proved to be unfortunate, inasmuch as the shade cast by the side of the tank made close observation somewhat difficult. Accordingly, some weeks later, the stone was removed and an attempt was made to remove the worm to a position more favourable for observation. The proximal end of the tube, however, had been imperceptibly worked by the worm beneath the small gravel which covers the bottom of the tank. A number of tiny pebbles had been cemented to the tube, and the tube itself cemented at a number of points to the bottom of the tank. On discovering this the Curator decided not to disturb the worm further. The distal, open end of the tube was now supported on the stone, in order to keep it out of the reach of neighbouring anemones, and still closer watch was kept upon the behaviour of the worm. Shortly afterwards it became evident that the worm was moving its tube bodily in the direction of its proximal end. A dark ring around the tube afforded a fixed point, by noting the position of which in relation to certain recognisable pebbles which lay near it the Curator was able to ascertain that the rate of movement was about 1 millimetre per 24 hours. At this rate the tube was moved at least 2 centimetres. Later on a slight elevation of the surface of the gravel was noticed beyond the point where the proximal end of the tube was known to be originally. Careful removal of the gravel by means of a large camel-hair pencil revealed an interesting state of affairs. The worm had made a considerable extension of its tube, consisting of the chitin with which the tube of *Sabella* is normally lined, and instead of mud the surrounding pebbles had been used to cover it. The tube was now carefully removed, and in doing this the Curator noticed that the extension was attached at many points by chitinous threads to the bottom of the tank. Measurements of the tube showed that its total length was 55·5 centimetres, 29·5 centimetres of which consisted of the original mud-invested tube, and 26 centimetres of the chitinous extension of the proximal end. Beginning at the point where the former condition merged into the latter, the pebbles were removed from 5 centimetres of the extension, a short length of glass tubing was slipped over the exposed portion and the tube placed in a well lighted part of the tank. For some days after this the posterior end of the worm could be seen moving slowly up and down the extension, and, ere long, several new pebbles were added to the extremity. Movement of the whole tube in the direction of the proximal end was again noticed, and this is still (October 18th) going on, though the daily rate of movement is slower. At the same time the worm has been adding to the open end of the tube, 8 millimetres of normal construction having been added in 21 days. It is worthy of note that since its removal to its present position the worm has not been seen expanded in the daytime, so that the addition to the open end of the tube must be carried on during the night. A little heap of excreta which lies immediately below the aperture of the tube tends to confirm this supposition.

"Before leaving the subject of tube-building Polychætes, it may be mentioned that *Serpula vermicularis*, *Potamilla reniformis* and *P. torelli* have appeared spontaneously and are now well established in several of the table tanks in the Aquarium. The latter species of *Potamilla* has not been previously recorded from the L.M.B.C. District.

"Early in May a large number of specimens of the brittle-star *Ophiocoma nigra* were found in a crab-pot which had just been brought in from the fishing grounds. Fifty of the largest were selected and placed in one of the table tanks, where they are still in vigorous health. The rapidity with which this brittle-star detects the presence of food is remarkable. A small bit of fish or mussel dropped into the tank attracts the attention of half the number of specimens in a few seconds, as shown by an almost simultaneous move towards it from different points. On one occasion the following experiment was made. At 10.15 a.m. a small piece of mussel was suspended by means of a thread about $\frac{5}{8}$ inch below the surface of the water. Its presence was detected by a number of the brittle-stars in 15 seconds. At 10.20 a.m. some of them had congregated together, not directly under the food, but about 3 inches to one side of it. At 10.30 a.m. six of them moved to a point underneath it, and raised their arms towards the surface of the water as if searching for it. As it appeared to be out of their reach it was lowered $\frac{1}{4}$ inch. Shortly afterwards one of them touched it with the extreme tip of one of its arms. Taking two or three turns of the tip of the arm around the bit of food the animal hauled itself up until the food was within reach of its mouth. A few seconds later a second specimen hauled itself up by the disengaged arms of the first, and this was quickly followed by a third. Both insinuated their arms between those of the first, and persistently tried to obtain possession of the food. Finding their efforts vain, they eventually dropped to the bottom of the tank. At 10.45 a.m. the food had been swallowed and disengaged from the thread by the first specimen.

"On Monday, July 3rd, the Assistant Curator called attention to a large number of specimens of *Aplysia punctata* which he had noticed on the beach, between tide marks, in the neighbourhood of the old Biological Station. The spot was immediately visited by the Curator, who found a considerable area of the beach thickly strewn with decaying sea-weeds, presumably thrown ashore during the prevalence of a fresh westerly breeze on the previous Saturday evening. Mixed up with the weed were hundreds of Aplysias, many of them 4 to 5 inches in length. At several points the Curator picked up six in the area of a square foot. Having been exposed to the warm sunshine for several hours many appeared to be lifeless when picked up, but from 80 to 90 specimens taken at random revived when put into fresh sea-water. No trace of this great incursion was to be seen two days later.

(Signed) H. C. CHADWICK."

Report of the Edward Forbes Exhibitioner.

An "Edward Forbes Exhibition" was founded* last year, at the University of Liverpool, in commemoration of the pioneer marine biological work done in this district by the celebrated Manx Naturalist, who was born about a hundred years ago. The object of the Exhibition is to enable some post-graduate student of the University to proceed to the Port Erin Biological Station for the purpose of carrying on some piece of biological research, more or less in continuation of some line of work opened up by Forbes, or an investigation which has grown out of such work.

The Edward Forbes Exhibitioner for the year 1916 is Emma Louise Gleave, M.Sc., who spent a couple of weeks at Port Erin in the spring and summer working at some points in the structure of the large Nudibranch, *Doris tuberculata*, with the view of preparing an L.M.B.C. Memoir on the subject. Miss Gleave reports as follows on her work at Port Erin :—

"I went to Port Erin on April 12th and returned to Liverpool on April 28th. When I arrived at the Biological Station I found that a number of specimens of *Doris tuberculata* had been collected by Miss Bamber and the Liverpool University students during the previous good tides, so that I was able to begin work on them immediately.

"I spent a considerable amount of time in narcotising these specimens, and discovered that fresh water added in small quantities to the sea water in which the animals were living was a much better narcotising agent than any I had tried previously, e.g., cocaine, chloroform. I used many of the freshly narcotised specimens for the study of the morphology of the reproductive ducts, by injecting carmine jelly and other coloured substances into different parts of the reproductive organs. I also took the opportunity of examining the eyes

* The Regulations in regard to the Exhibition will be found at p. 70.

in these specimens under the binocular, as in this condition their structure is far more clearly seen than in fixed material.

"During the good tides I collected not only additional specimens of Doris, but also a considerable amount of the spawn which is abundant on the rocks at this time of the year, its presence being in fact the best guide in the search for adult specimens, which are themselves much less conspicuous than the spawn. Unfortunately, the development of the eggs will not proceed successfully for any length of time in the aquarium tanks, so that I was obliged to collect pieces of spawn in different stages of development. *Intra vitam* staining of the veligers with neutral red gave interesting results.

"I fixed a considerable amount of material for further investigation in Liverpool.

"My second period at Port Erin was from August 21st to 28th, when I was unable to do any further work on the living animals for want of fresh material, which could not be obtained at that time of year.

"I gladly acknowledge the help afforded me by the Biological Station, both in connection with the collection of the necessary material, and also in the subsequent work upon it. I hope to complete the investigation in the University Laboratory of Zoology, at Liverpool.

(Signed) E. L. GLEAVE."

L.M.B.C. MEMOIRS.

Since our last report was published, no further Memoirs have been issued to the public. HIMANTHALIA, by Miss L. G. Nash, M.Sc., is ready to print; Miss E. L. Gleave, M.Sc., has nearly completed her Memoir on DORIS, the Sea-lemon; Mr. Burfield, who was writing the Memoir on SAGITTA, has joined the Army; Miss Bamber has made some progress with TUBULARIA, and still other Memoirs 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, 88 pp., 6 Pls.
XXII. Echinoderm Larvæ, H. C. Chadwick, 40 pp., 9 Pls
XXIII. Tubifex, G. C. Dixon, 100 pp., 7 Pls.
Himanthalia, L. G. Nash.
Doris, E. L. Gleave.
Tubularia, R. C. Bamber.
Aplysia, N. B. Eales.
Sagitta, S. T. Burfield.
Actinia, J. A. Clubb.
Zostera, R. Robbins.
Halichondria and Sycon, A. Dendy.

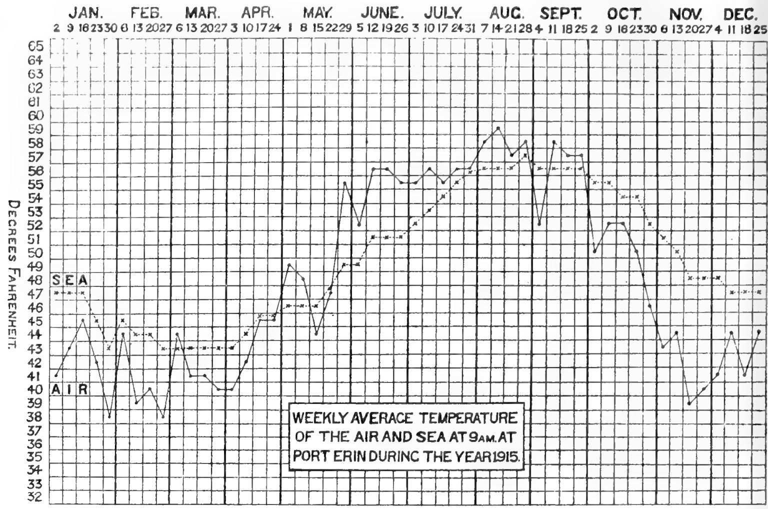
OYSTER, W. A. Herdman and J. T. Jenkins.
SABELLARIA, A. T. Watson.
OSTRACOD (CYTHERE), A. Scott.
ASTERIAS, H. C. Chadwick.
PYCNOGONUM, J. E. Hamilton.
BOTRYLLOIDES, W. A. Herdman.

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

As the result of a slight fire in the Zoology Department of the University, a portion of the stock of L.M.B.C. Memoirs has been partially destroyed. There are a certain number of damaged copies of some of the Memoirs which are stained or singed externally, but are still quite usable, and are suitable for laboratory work. The Committee has decided to offer these at prices ranging according to the condition from one-half to one-fourth of the published prices, as follows :— Memoir I., Ascidia, 6d. to 9d. ; VI., Lepeophtheirus and Lernæa, 6d. to 1s. ; VII., Lineus, 6d. to 1s. ; XIII., Anurida, 1s. to 2s. ; XIV., Ligia, 6d. to 1s. ; XV., Antedon, 6d. to 1s. 3d.

Orders for these damaged copies should be sent to Professor Herdman, the University, Liverpool. New copies of any of the Memoirs should be ordered from Williams & Norgate.

The diagram of sea and air temperatures for 1916, compiled by Mr. Chadwick from his daily records, is not yet completed ; but that for the preceding year, 1915, is 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.



Appended to this Report are :—

(A) An Address on "Sir Wyville Thomson and the Challenger Expedition," delivered to the Biological Society, by Prof. Herdman, on November 10th, 1916;

(B) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations—with Memoranda for the use of students, and the Regulations in regard to the "Edward Forbes Exhibiton" at the University of Liverpool;

(C) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet for the year.

Appendix A.

AN ADDRESS UPON

SIR C. WYVILLE THOMSON AND THE "CHALLENGER" EXPEDITION.

GIVEN BEFORE THE LIVERPOOL BIOLOGICAL SOCIETY

By W. A. Herdman.

It seems appropriate to follow up the address I gave last year on the life and work of the great Manx Naturalist and early Oceanographer, Professor Edward Forbes—whose centenary we were then celebrating—by some account of the scientific career of that later Oceanographer, Sir Wyville Thomson, whose name will go down through the ages as the leader of the famous "Challenger" Deep-Sea Exploring Expedition. There are many links between these two men. Both were Naturalists in the widest sense, with an extensive knowledge of the Natural Sciences and a great appreciation of Nature in all its aspects. Each occupied at the end of his life the Chair of Natural History in the University of Edinburgh, though neither had time to develop the great school of Marine Biology which might have been expected from such men in such a place had opportunity permitted. Forbes was only 15 years the senior, and was at the zenith of his fame—publishing epoch-making views on the distribution of living things in the sea—at the time when Thomson entered the University of Edinburgh, and no doubt these views would arrest the attention and guide the thoughts of any keen young student of the Natural Sciences. It was Forbes who, on a basis of observations which were then thought to be sufficient, but are now known to be exceptional, placed the zero of life in the sea at 300 fathoms or thereabouts, and it was Wyville

Thomson more than any man who proved that Forbes' views were in this particular erroneous, and that many and varied living things inhabit the greatest depths of the ocean. It may seem to some of us that Forbes lived very long ago, in a remote period of last century, but Wyville Thomson bridges over the gap to our time. He knew Edward Forbes, and I was fortunate enough to be the student, and later on assistant, of Sir Wyville Thomson. It is then, you will realise, a peculiar satisfaction to me to make known to a younger generation of marine biologists what I am able to recollect or recover as to the life-work of my revered master, and as to the part he played in that great development of Oceanography as a Science which characterised the latter part of the Nineteenth Century.

Charles Wyville Thomson was born on March 5th, 1830, at his ancestral country house of Bonsyde, within sight of the famous loch and ruined royal palace of Linlithgow, and not far from the shores of the Firth of Forth. His family had been connected with Edinburgh and the neighbourhood for generations, his great grandfather, for example, being a law officer of the Crown at the time of the Jacobite rising in 1745. He was educated at Merchiston Castle School, formerly the home of Napier the inventor of logarithms, and, as in the case of some other men of Science, his favourite study at school was, we are told, the Latin poets. We are apt to forget that in these cases there was probably no science taught in the school, and no opportunity given to the boy of studying anything more interesting than the Odes of Horace.

At the age of 16 he matriculated as a student of Medicine in the University of Edinburgh, but his main interests were said to be Zoology, Botany, and Geology, and he was suspected of sometimes wandering as an observer and collector of marine invertebrates along the prolific shores of the Firth, when he ought according to rules and regulations to have been engaged with lectures and text-books. Like many of the more intelligent students of science in Edinburgh, both at that time and later, he joined the Royal Physical Society—which despite its name is a Society of Natural History—and for a couple of years he filled the office of Secretary, surely one of the youngest on record. Fortunately for Oceanography, after about three years of study, ill-health caused our young Naturalist to give up all idea of the Medical profession, and to turn his attention definitely to the Natural Sciences as his life-work. He left the University in 1850, without taking a degree, but his ability and reputation were such that he made rapid progress in the chosen career, and filled successively the posts of lecturer on Botany in the University of Aberdeen (1851), professor of Natural History in Queen's College, Cork (1853), professor of Geology in Belfast (1854), and a few years later (1860) professor of Zoology and Botany in the same college. It will be noticed that, like Edward Forbes, Wyville Thomson was capable of filling with success posts in all the Natural Sciences in succession, and this wide range of interest and of knowledge was of course of immense advantage in the great work that was to come in exploring the oceans.

The Rev. Dr. Hamilton, Vice-Chancellor of the Queen's University of Belfast, himself a former student and assistant of Prof. Wyville Thomson, has most kindly provided me with notes of his recollections of those days. I am sorry it is impossible to print these in full, but I extract from them the following impressions:—Thomson had a bright handsome face and a light springy step; he was a delightful and instructive lecturer, who had on his table a profusion of specimens of which he made incessant use, but spoke without notes. His Saturday excursions must have been delightful. We have a picture of him striding along, vasculum on back, at the head of his students, pointing out specimens and objects of interest as they were encountered. His hospitality to his students has left pleasant memories of the music and games at their social evenings. Amongst other activities at Belfast he took a prominent position at the Natural History and Philosophical Society, the Belfast Naturalists' Field Club, and also the Literary Society, at all of which he read papers. We hear that he gloried in his beautiful garden and was a valued judge at the local flower shows.

It was during this period of teaching at Belfast that he began to make his mark in the scientific world as a marine biologist who studied animals both living and extinct, and published his investigations on British Coelenterates and Polyzoa and on fossil Cirripedes and Trilobites. In working at Palaeontology he became interested in fossil Crinoids, and so was led to the investigation of their only living representatives in our seas—the Rosy Feather Stars—a study which we shall see led him step by step to the great climax of his career, the leadership of the "Challenger" Expedition. In 1862 Thomson completed his well-known memoir "On the Embryogeny of *Antedon rosaceus*" (published in the Philosophical Transactions of the Royal Society for 1865), illustrated by a beautiful series of drawings representing the development and structure of the "pentacrinoid" stages in the life history of the young Antedon.

It was at this time, also, that he became interested in those questions concerning life in the great depths of the ocean, the elucidation of which was to be his life-work and make him famous. It will be remembered that Edward Forbes, from his observations in the Mediterranean (an abnormal sea in some respects), regarded depths of over 300 fathoms as an azoïc zone. It was the work of Wyville Thomson and his colleagues on various successive dredging expeditions to prove conclusively, what was beginning to be suspected by Naturalists, that there is no azoic zone in the sea, but that abundant life belonging to many groups of animals extends down to the greatest known depths of from four to five thousand fathoms—nearly six statute miles from the surface. We can trace the gradual growth of Thomson's ideas in regard to the sea with the natural widening of his scope—from collecting as a student on the shores of the Firth of Forth to dredging as a young professor along the coasts of Ireland, and then to the successive deep-water expeditions in the surveying vessels "Lightning" and "Porcupine," and finally to the great world-wide exploring voyage of the "Challenger." We can also trace the steps in his Echinoderm studies which seem to have led him to the fruitful field of deep-sea exploration. Palaeontological investigation suggested work on living Crinoids, and the news that a strange new stalked Crinoid (*Rhizocrinus*), related to the fossil Apiocrinidae, had been found living in Northern seas induced him, in 1866, to visit Professor Michael Sars at Christiania, and examine for himself the remarkable collection of rare animals that his son, George Ossian Sars, had brought up from deep water (over 300 fathoms) in the Lofoten fjords. He was struck by their novelty and deep interest and by their resemblance to and bearing upon some of the extinct animals of former geological periods, and especially of the Chalk.

Thus inspired, he urged his friend Dr. W. B. Carpenter, with whom he was then working at the later development of Antedon, to join him in endeavouring to promote an expedition to explore the deep waters of the Atlantic along the north-west coasts of Europe. Dr. Carpenter's powerful advocacy induced the Council of the Royal Society to use its influence with the Hydrographer, with such success that the Admiralty consented to place first one and then another small surveying steamer at the disposal of a Committee of scientific experts, for expeditions under the leadership of the two enthusiasts. After the first summer a third Naturalist of European fame, Dr. Gwyn Jeffreys, author of the five volumes on British Conchology, joined Carpenter and Thomson in conducting the practical work at sea; and the account of how, in 1868, H.M.S. "Lightning" and, in 1869 and 1870, H.M.S. "Porcupine" were equipped by the Admiralty and sent out to explore the depths, from the Faroes in the North to Gibraltar and beyond in the South, is given in full detail in Wyville Thomson's great work "The Depths of the Sea," which may be regarded as the first general text-book of Oceanography. It was published* just as the "Challenger" Expedition was leaving England, and so gives us a statement of matters and opinions up to that important point in the history of the science. It is too long to summarise; let me give you some idea of its contents by quoting a few passages, and stating a few facts:—

"The surveying ship 'Lightning'" (Sir Wyville writes, p. 57) "was assigned for the service—a cranky little vessel enough, one which had the somewhat doubtful title to respect of being perhaps the very oldest paddle-steamer in Her Majesty's navy. We had not good times in the 'Lightning.' She kept out the water imperfectly, and as we had deplorable weather during nearly the whole of the six weeks we were afloat, we were in considerable discomfort. The vessel, in fact, was scarcely seaworthy, the iron hook and screw-jack fastenings of the rigging were worn with age, and many of them were carried away, and on two occasions the ship ran some risk."

Still, on this "cranky little vessel" in the rough seas of the North Atlantic, they dredged down to 600 fathoms; and in 1869 on the "Porcupine," a more sea-worthy ship, they got successful hauls from the great depth of 2,435 fathoms, nearly 3 statute miles.

Part of the book is historical, and amongst other interesting matters gives an account of those earlier observations which afford glimpses of a fauna in the deep sea. For example, we are told how in 1860 Professor Fleeming Jenkin, in repairing a cable in the Mediterranean, found several animals, including

* Macmillan & Co., London, 1873.

a deep sea coral, attached to the broken cable at a depth greater than 1,000 fathoms, and therefore much beyond the supposed zero of Edward Forbes. During the "Lightning" and "Porcupine" expeditions, 16 hauls of the dredge were taken at depths beyond 1,000 fathoms, and two in depths greater than 2,000 fathoms, and in all cases life was found to be abundant.

Let us quote here Wyville Thomson's account of a remarkable discovery made by one of these hauls, viz., that of the first living representative of the fossil flexible sea-urchins of the Chalk ever seen by a scientific man (p. 155) :—

"This haul was not very rich, but it yielded one specimen of extraordinary beauty and interest. As the dredge was coming in we got a glimpse from time to time of a large scarlet urchin in the bag. We thought it was one of the highly-coloured forms of *Echinus flemingii* of unusual size, and as it was blowing fresh and there was some little difficulty in getting the dredge capsized, we gave little heed to what seemed to be an inevitable necessity—that it should be crushed to pieces. We were somewhat surprised, therefore, when it rolled out of the bag uninjured; and our surprise increased, and was certainly in my case mingled with a certain amount of nervousness, when it settled down quietly in the form of a round red cake, and began to pant—a line of conduct, to say the least of it, very unusual in its rigid undemonstrative order. Yet there it was with all the ordinary characters of a sea-urchin, its inter-ambulacral areas, and its ambulacral areas with their rows of tube feet, its spines, and five sharp blue teeth; and curious undulations were passing through its perfectly flexible leather-like test. I had to summon up some resolution before taking the weird little monster in my hand, and congratulating myself on the most interesting addition to my favourite family which had been made for many a day."*

* Wyville Thomson gave a detailed description of this and the other new Echinoidea obtained on the "Porcupine" Expeditions in his Memoir, published in the Philosophical Transactions of the Royal Society for 1874.

I shall quote one more description (p.160) of a haul of a dredge supplied with rope "tangles" from deep water :—

"I do not believe human dredger ever got such a haul. The special inhabitants of that particular region—vitreous sponges and echinoderms—had taken quite kindly to the tangles, warping themselves into them and sticking through them and over them, till the mass was such that we could scarcely get it on board. Dozens of great *Holteniae*, like

'Wrinkled heads and aged,
With silver beard and hair.'

a dozen of the best of them breaking off just at that critical point where everything doubles its weight by being lifted out of the water, and sinking slowly away back again to our inexpressible anguish ; glossy wisps of *Hyalonema* spicules ; a bushel of the pretty little mushroom-like *Tisiphonia* ; a fiery constellation of the scarlet *Astropecten tenuispinis* ; while a whole tangle was ensanguined by the 'disjecta membra' of a splendid *Brisinga*."*

In the final chapters of the book he discusses such highly important and controversial matters as Deep-sea Temperatures, the Gulf Stream and the Continuity of the Chalk. In summarising the results obtained in regard to the deep-sea fauna, he says (p. 80) :—

"Finally, it had been shown that a large proportion of the forms living at great depths in the sea belong to species hitherto unknown, and that thus a new field of boundless extent and great interest is open to the naturalist. It had been further shown that many of these deep-sea animals are specifically identical with tertiary fossils hitherto believed to be extinct, while others associate themselves with and illustrate extinct groups of the fauna of more remote periods ; as, for example, the vitreous sponges illustrate and unriddle the ventriculites of the chalk."

* For descriptions and figures of *Holtenia* and other new deep-sea Hexactinellid Sponges, see his Memoir in the Phil. Trans. Royal Soc. for 1869.

These pioneering expeditions—the results of which are not even yet fully made known to the scientific world—were epoch-making inasmuch as they not only opened up this new world to the systematic marine biologist, but gave glimpses of world-wide problems in connection with the physics, the chemistry and the biology of the sea which are only now being adequately investigated by the modern Oceanographer. These results, which aroused intense interest amongst the leading scientific men of the time, were so rapidly surpassed and overshadowed by the still greater achievements of the "Challenger" and other National Exploring Expeditions that followed in the seventies and eighties of last century, that there is some danger of their real importance being lost sight of; but it ought never to be forgotten that they first demonstrated the abundance of life of a varied nature in depths formerly supposed to be azoic, and, moreover, that some of the deep-sea animals were related to extinct forms belonging to Jurassic, Cretaceous and Tertiary periods.

Naturally Wyville Thomson, the young (then about forty) and active originator and leading spirit of these new and successful investigations, became a famous man. In 1869 he was elected to the fellowship of the Royal Society, and in 1870 he succeeded Allman as professor of Natural History in the University of Edinburgh, the post held by Forbes some 15 years before. Thomson was a fluent and lucid lecturer, and a successful professor, greatly appreciated by his many students. His classes at Edinburgh were amongst the largest in the University, and were probably unequalled in size by any classes of Zoology elsewhere in the country. Had time and strength permitted, he might have developed a great school of Marine Biology in connection with his University, but larger schemes further afield almost immediately claimed his attention.

The undoubted success of the preliminary expeditions in the "Lightning" and "Porcupine" encouraged Carpenter and Wyville Thomson, again through the Council of the Royal Society, to induce the Government to equip a deep-sea expedition on a really grand scale to explore and make known the conditions of life in the great oceans. This resulted in the famous circumnavigating expedition in H.M.S. "Challenger," and Professor Wyville Thomson as the chief originator of the expedition was appointed Director of the civilian scientific staff on board.

The "Challenger" Expedition will rank in history with the voyages of Vasco da Gama, Columbus, Magellan and Cook. Like these it added new regions of the globe to our knowledge, and the wide expanses thus opened up for the first time—the floors of the oceans—were vaster than the discoveries of any previous exploration.

H.M.S. "Challenger" was a spar-deck corvette of 2,306 tons displacement, with auxiliary engines of 1,234 indicated horse-power. She sailed in December, 1872, and returned in May, 1876, and during these 3½ years she traversed about 69,000 miles in the Atlantic and Pacific Oceans, and penetrated as far south as the Antarctic ice barrier. Soundings and dredgings or trawlings were taken at 362 stations, and enormous collections, such as the scientific world had never seen before, of marine organisms large and small, and of samples of bottom deposits and of water from all depths and all latitudes, were brought home for detailed investigation. As Sir Ray Lankester has said, "never did an expedition cost so little and produce such momentous results for human knowledge." A number of preliminary reports written during the voyage were sent from the "Challenger" by Wyville Thomson, as Director, to the Hydrographer of the Admiralty, and were published by the Royal Society in 1875 and 1876*. Some were written by the Director himself, others were reports to him by the other members of the Scientific Staff. Thus, Moseley reported on

* See especially Proc. Roy. Soc., No. 170, 1876.

the more remarkable Hydroids and Corals discovered, Murray on the deep-sea deposits and on the surface organisms, von Suhm on some of the Crustacea and their larval forms, and Buchanan on the physics and chemistry of the sea. All these preliminary reports are of interest even now to look over, and must have been far more so forty years ago, when they were published, as they gave the first glimpses of a world of new knowledge which was afterwards elaborated and displayed in the finished series of "Challenger Reports," and has now found its way into text-books and been incorporated in the fabric of established science.

The long voyage, a considerable part of it spent in the tropics, cannot but have affected to some extent the health of men not trained to a life at sea. One of the Naturalists, Dr. R. von Willemoes-Suhm, died during the voyage; Sir Wyville Thomson's health broke down soon after his return, and he died early in 1882; Professor Moseley died comparatively young in 1891, after some years of ill-health. Sir John Murray, on the other hand, was still in vigorous health at the age of over 72, when he was killed in a motor accident in 1914. Dr. Buchanan, the Chemist to the Expedition, is now the sole survivor of the Civilian Scientific Staff. The members of that staff were all brilliant men, who all produced most distinguished work. It had been said of Moseley, when a young man, that you had only to put him down on a hillside with a piece of string and an old nail, and in an hour or two he would have discovered some natural object of surpassing interest. During the voyage, in addition to working at the groups of animals, such as Corals, entrusted to his care, he made very notable collections in Botany and Anthropology from the remote and little-known islands that were visited. He also investigated some of the more remarkable of the organisms encountered either on sea or land, such as a pelagic Nemertean and some deep-sea Ascidians. While the

"Challenger" was at Cape Town he took advantage of the opportunity to search for Peripatus, at Wynberg, on the slopes of Table Mountain, and on his first-found living specimen succeeded in demonstrating its essentially Tracheate nature.

In his book "Notes of a Naturalist on the 'Challenger,'" Professor Moseley gives us an interesting account of the deep-sea dredging and sounding, and of the length of time required for these operations on board the "Challenger." At a depth of 4,500 fathoms the sounding weight took an hour and a quarter to reach the bottom, and a much longer time to wind in again. It used to take all day to dredge and trawl at any considerable depth, and the net was usually got in only at night-fall. The ship, when dredging, used to lie rolling about all day drifting along with the wind and dragging the dredge slowly over the bottom. "At last, in the afternoon, the dredge-rope was placed on the drum, and wound in for three or four hours, sometimes longer. Often the rope or net, heavily weighted with mud, hung on the bottom, and there was great excitement as the strain gradually increased on the line. On several occasions the rope broke, and the end disappeared overboard, three or four miles of rope and the dredge being thus lost. At first, when the dredge came up, every man and boy in the ship who could possibly slip away, crowded round it, to see what had been fished up. Gradually, as the novelty of the thing wore off, the crowd became smaller and smaller . . . . and as the same tedious animals kept appearing from the depths in all parts of the world, the ardour of the scientific staff even abated somewhat, and on some occasions the members were not all present at the critical moment, especially when this occurred in the middle of dinner-time, as it had an unfortunate propensity of doing. It is possible even for a naturalist to get weary of deep-sea dredging. Sir Wyville Thomson's enthusiasm never flagged, and I do not think he ever missed the arrival of the net at the surface."*

* "Notes of a Naturalist on the 'Challenger,'" p. 501.

The conditions under which life exists in the deep sea are very remarkable. The pressure due to the weight of water is enormous, and amounts roughly to a ton on the square inch for every thousand fathoms; so that at 5,000 fathoms the pressure is about 5 tons, that is, between seven and eight hundred times as great as the 15 lbs. on the square inch we are accustomed to at sea level. On one occasion we are told that Mr. Buchanan, the Chemist to the Expedition, hermetically sealed up a thick glass tube, wrapped it in flannel, and enclosed it in a wide copper tube with perforated ends, and then lowered the whole to a depth of 2,000 fathoms and hauled it up, when it was found that the copper tube was flattened by the pressure, and the glass tube inside the flannel was reduced to a fine powder like snow. This process was referred to by Sir Wyville Thomson as an "implosion," the converse of an explosion. The most delicate animals, however, are able to exist under these enormous pressures, as their tissues are permeated by fluids under the same pressure, and are consequently supported equally on the inside and the outside. It is only when some animal is brought up too suddenly from a great depth to the surface that the release of pressure has a disastrous effect. Some fishes arrive with their eyes burst out of their heads, their scales forced off, and other parts of the body horribly distorted.

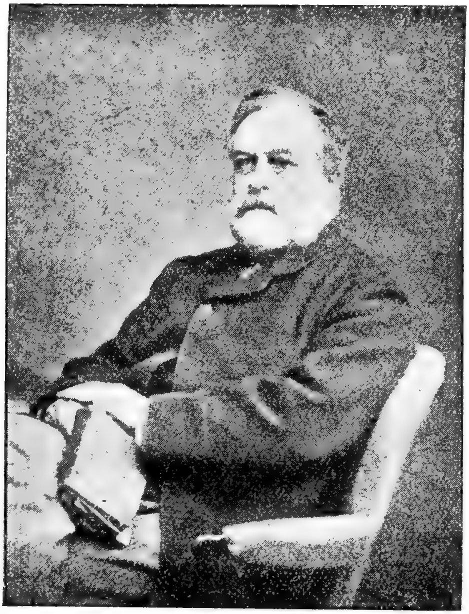
The temperature in these great depths is at or about freezing point; and, as the sunlight probably only penetrates for a few hundred fathoms, there must be total darkness with the exception of occasional dim, ghostly glimmers of light given out by phosphorescent animals.

Moseley gives an amusing account of their tame and somewhat dilapidated parrot who, from his perch on one of the wardroom hat-pegs, talked away constantly and amused them during the whole voyage. His great triumph, we are told, was frequently to repeat, "What! 2,000 fathoms and no bottom! Ah, Dr. Carpenter, F.R.S.!"

On the return of the Expedition, Wyville Thomson was appointed Director of the "Challenger Expedition Commission" for the purpose of seeing to the distribution and investigation of the vast collections, and the publication of the results. In selecting specialists to prepare the reports, Thomson and his successor Murray very wisely chose the best men available, irrespective of nationality. Consequently, the fifty quarto volumes of reports contain some of the best work of the most distinguished naturalists of all countries. It was not, however, until twenty years after the expedition that the last of these volumes was issued, and the last of the collections was safely deposited in the British Museum.

It is unfortunate that the man of science has so frequently to make a choice between the necessary work of administration and original research. Let us trust that he does not invariably select the work for which he is least fitted. Sir Wyville Thomson was given little time for either. In the few years of work that remained before his health gave way, he was so occupied with his many and varied duties as Director of the Commission and Editor of the Reports, that there was little time for the original work he had planned to do in connection with the collections of Stalked Crinoids and of Hexactinellid Sponges—the two groups that he had reserved for his own investigation, and upon which he was an acknowledged authority.

He was knighted in 1876, and was awarded one of the gold medals by the Royal Society. In 1877, he delivered the Rede Lecture at Cambridge, and in the following year presided over one of the sections of the British Association at Dublin. It was during these years, after the return of the Expedition, that I was privileged to know him, first as a senior student and young Assistant and then as Naturalist on the "Challenger" Commission, when I had priceless opportunities of becoming acquainted with the wonderful collections, and with the distinguished men from all countries who came to Edinburgh to study them and to consult with Sir Wyville Thomson and with his Chief Assistant, Dr. Murray, afterwards Sir John. To mention just a few of those I recollect most vividly, either at the "Challenger Office" or at Sir Wyville's hospitable house of Bonsyde, where I had frequently to help him in the editing of the first few volumes of reports, or by taking



SIR C. WYVILLE THOMSON.

some of his more energetic distinguished guests out for a walk round the countryside, listening rather awe-struck to their wonderful conversation (it was frequently a monologue, and I believe I acquired merit as a good listener), there were :—that veteran of science, Dr. W. B. Carpenter, Professor Huxley, Moseley, Hubrecht, Ernst Haeckel, Alexander Agassiz, McIntosh, Percy Sladen, the Abbé Renard, Hjalmar Théel, Sir William Turner, Canon Norman, Professor P. G. Tait, Hoek, Perceval Wright, and a number of younger men who have since attained distinction, but were then just launched on a scientific career. During that time the distribution of many of the groups of animals to specialists, and the form in which the Reports were to be published, was being decided on, and many interesting details had to be arranged between Sir Wyville and his "Reporters" on the one hand, and the Stationery Office of the Government (which undertook the publication) on the other, the latter seeming to have great difficulty in understanding the curious requirements of scientific authors in regard to printing and illustration.

During this time at home Sir Wyville published* his preliminary account of the general results of the expedition, in two volumes, entitled "Voyage of the 'Challenger'—The Atlantic"—which were to have been followed by companion volumes on the Pacific that, unfortunately, never appeared. "The Atlantic" is a most readable work, full of observations on the Botany, Geology and Antiquities of the places visited as well as on the Marine Biology of the cruise. A notable feature of the book is the series of really beautiful text-figures illustrating the new species of Echinodermata and Sponges, which Professor Thomson had to some extent investigated during the voyage, and which he briefly described in these two volumes. Some of the figures of Holothurians, Sea-urchins and Star-fishes show interesting cases of "direct development" of deep water or antarctic Echinoderms, where the young were found in curiously devised marsupial cavities and had evidently never passed through a free larval stage.

I shall quote here a couple of passages from "The Atlantic," to give some idea of the varied interest of the book and of Sir Wyville's descriptive power.

* Macmillan & Co., London, 1877.

In writing of the masses of weed in the Sargasso Sea, he says,* "The floating islands have inhabitants peculiar to them, and I know of no more perfect example of protective resemblance than that which is shown in the gulf-weed fauna. Animals drifting about on the surface of the sea with such scanty cover as the single broken layer of the sea-weed, must be exposed to exceptional danger from the sharp-eyed sea-birds hovering above them, and from the hungry fishes searching for prey beneath; but one and all of these creatures imitate in such an extraordinary way, both in form and colouring, their floating habitat, and consequently one another, that we can well imagine their deceiving both the birds and the fishes. . . . . A little short-tailed crab (*Nautilograpsus minutus*) swarms on the weed and on every floating object, and it is odd to see how the little creature usually corresponds in colour with whatever it may happen to inhabit. These gulf-weed animals, fishes, mollusca, and crabs, do not simply imitate the colours of the gulf-weed; to do so would be to produce suspicious patches of continuous olive; they are all blotched over with bright opaque white, the blotches generally rounded, sometimes irregular, but at a little distance absolutely undistinguishable from the patches of *Membranipora* on the weed."

On one occasion he describes (p. 147) the loss of a great catch, when trawling at a depth of 2,350 fathoms in the South Atlantic. "The trawl was lowered, and on heaving in it came up apparently with a heavy weight, the accumulators being stretched to the utmost. It was a long and weary wind-in on account of the continued strain; at length it came close to the surface, and we could see the distended net through the water; when, just as it was leaving the water, and so greatly increasing its weight, the swivel between the dredge-rope and the chain gave way, and the trawl with its unknown

* Atlantic, Vol. II, p. 10.

burden quietly sank out of sight. It was a cruel disappointment, every one was on the bridge, and curiosity was wound up to the highest pitch: some vowed that they saw resting on the beam of the vanishing trawl the white hand of the mermaiden for whom we had watched so long in vain; but I think it is more likely that the trawl had got bagged with the large sea-slugs which occur in some of these deep dredgings in large quantity, and have more than once burst the trawl net."

Here is a record of an historic event in our knowledge of the Protozoa (p. 293):—

"On one occasion in the Pacific, when Mr. Murray was out in a boat in a dead calm collecting surface creatures, he took gently up in a spoon a little globular gelatinous mass with a red centre, and transferred it to a tube. This globule gave us our first and last chance of seeing what a pelagic foraminifer really is when in its full beauty. When placed under the microscope it proved to be a *Hastigerina* in a condition wholly different from anything which we had yet seen. The spines, which were mostly unbroken, owing to its mode of capture, were enormously long, about fifteen times the diameter of the shell in length; the sarcode, loaded with its yellow oil-cells, was almost all outside the shell, and beyond the fringe of yellow sarcode the space between the spines to a distance of about twice the diameter of the shell all round was completely filled up with delicate *bullae,* like those which we see in some of the Radiolarians, as if the most perfectly transparent portion of the sarcode had been blown out into a delicate froth of bubbles of uniform size. Along the spines fine double threads of transparent sarcode, loaded with minute granules, coursed up one side and down the other, while between the spines independent thread-like pseudopodia ran out, some of them perfectly free, and others anastomosing with one another or joining the sarcodic sheaths of the spines, but all showing the characteristic flowing movement of living protoplasm. The woodcut (Fig. 52), excellent though it is gives only a most imperfect idea of the complexity and the beauty of the organism with all its swimming or floating machinery in this expanded condition."

The conclusion at which Wyville Thomson arrived from a consideration of deep-sea and shallow-water faunas was (p. 331) :—

"It would seem that the enormous pressure, the utter darkness, and the differences in the chemical and physical conditions of the water and in the proportions of its contained gases depending upon such extreme conditions, do not influence animal life to any great extent."

During these few years after the return of the "Challenger" a number of lithographic plates illustrating the new Stalked Crinoids and the new Hexactinellid Sponges of the expedition were drawn on stone under Sir Wyville's direction, and were afterwards made use of in the completed reports on the former group by Dr. P. H. Carpenter, and on the latter by Professor F. E. Schulze.

Even after his health began to give way, he arranged for and directed, even if he did not actually conduct, a very important subsidiary expedition for the purpose of investigating further the very remarkable conditions of temperature and fauna which had been noticed in the Faroe Channel during the earlier cruises in the North Atlantic.

Carpenter and Wyville Thomson, during their preliminary investigations in the "Lightning" and "Porcupine," had found that the Faroe Channel between Cape Wrath and the Faroe Isles was abruptly divided into two regions under very different conditions—a "cold" and a "warm" area. The temperature of the water to a depth of 200 fathoms is much the same in the two areas ; but in the cold area to the N.E. the temperature is about 34° F. at 250 fathoms and about 30° at the bottom in 640 fathoms, while in the warm area which stretches S.W. from the line of demarcation the temperature is 47° F. at 250 fathoms, and 42° at the bottom in 600 fathoms. The warm area was found to have 216 species, while the cold had 217, and of these only 48 species were common to both.

Sir Wyville Thomson (see "Nature," Sept. 2nd, 1880), as a result of his consideration of the "Challenger" temperatures, came to the conclusion that the cold and warm areas of the Faroe Channel must be separated by a very considerable submarine ridge rising to within 200 or 300 fathoms of the surface. He therefore addressed a letter in June, 1880, to the Hydrographer of the Admiralty, pointing out these facts, and asking for the use of a surveying vessel for a few weeks for the purpose of sounding the Faroe Channel with a view of testing his prediction. That was the origin of the "Knight Errant" expedition conducted by Captain Tizard and Dr. John Murray, under the general direction of Sir Wyville Thomson, who remained at Stornoway in the Outer Hebrides, during the four traverses of the region in question. The results* completely justified Sir Wyville Thomson's prediction, and showed that a ridge rising to within 300 fathoms of the surface runs from the N.W. of Scotland by the Island of Rona to the southern end of the Faroe fishing banks.

This was followed by a further expedition in H.M.S. "Triton," in the summer of 1882, again under Murray and Tizard, which was very fruitful of zoological results. The discovery of two very different assemblages of animals living on the two sides of the Wyville Thomson ridge—arctic forms to the North and atlantic forms to the South—gives us a notable example of the effect of the environment on the distribution of marine forms of life.

Sir Wyville Thomson, however, did not live to see the

* Published in the Proc. Roy. Soc. Edin. for 1882 (Vol. XI).

"Triton" expedition and the full results of the exploration of the submarine ridge which so appropriately bears his name. His health had been failing for several years. In June, 1879, he had an attack of paralysis, and had to give up most of his University work. He resigned his professorship in October, 1881, and the Directorship of the Challenger Commission at the end of that year. He was able, in an invalided condition, to attend the Jubilee Meeting of the British Association, at York, in August, 1881, and died at Bonsyde, on March 10th, 1882, in his 53rd year. He was a man of handsome presence and genial nature, with great personal charm of manner. His general culture, large fund of information on many subjects, his aptness and humour in conversation all contributed to make him a social success in Edinburgh and the beau-ideal of a host in his country home, where he gathered round him a large circle of friends by no means confined to scientific men.

He had a quaint way of occasionally bringing in old Scots sayings, or snatches of poetry, as for example, when he thought a question unimportant :—

> "Twenty peacocks in the air. I wonder how they all
> got there.
> I don't know—and I don't care!"

or—more briefly—"Twenty Peacocks."

Judged from the scientific point of view, he probably turned out less original work than might have been expected. He is to be regarded as one of those who promoted science quite as much by his tact, influence and personality as by his own researches. Much that he had planned and begun was never completed, much that he might have done was prevented by his stirring life, frequent changes of post, his important administrative work and his numerous social duties. He was inspiring in conversation, kindly in his help and advice to younger workers, sagacious in counsel and highly valued by a wide circle of scientific friends in this country, in America, and on the Continent.

The important question now to be considered is, how has the "Challenger" expedition, which we owe mainly to the inspiration and the energy of Sir Wyville Thomson, advanced the science of the sea? This may be answered under various heads, and many leading authorities in different branches of Oceanography have given their answer during the forty years that have elapsed since the expedition took place.

To take Hydrography first, it must be remembered that every contribution to our knowledge of the ocean currents and their character, the ocean floor, its nature and depth, the prevalent winds and meteorological and magnetical conditions is an addition to the safety of the sailor, to the ease and speed with which a voyage may be accomplished, and to the intercourse of nations. "Every Briton is proud of Britannia's navy; but let us remember that it is something more than our Empire's fighting machine, that it has been in the past, and will be still more in the future, the servant of the world, and a most potent agent in the peaceful union and advance of all its peoples."

Captain Tizard, who was the Navigating Officer on the "Challenger" during the expedition, tells us that the naval officers on board, equally with the scientific men, were all animated with the idea that it was their business to make the expedition a success, and we understand that while each member of the staff had his own work-room, in which he could pursue his own subject uninterruptedly, they all compared notes and got suggestions from one another in the smoking circle after dinner; a function which, we are told, was always well attended, and where the events and work of the day were freely and amicably discussed.

The chief hydrographic results which have benefited navigation are, according to Tizard :—

(1). The proof that the variation of the compass can be determined as accurately in a ship as on shore, if the ship is magnetically suitable.

(2). The determination for the first time of the depths and main contour lines of the great ocean basins. It was shown that some of the great depths formerly reported had been much exaggerated, and the deepest sounding obtained was 4,475 fathoms, in the neighbourhood of the Marianna Islands in the N. Pacific. The investigations of many other expeditions (such as the "Tuscarora," the "Gazelle," the "Vettor Pisani," and the "Valdivia") since the "Challenger" have not altered in any material degree the contour lines of the great oceans drawn by our expedition in 1876, and have not resulted in the discovery of any depth exceeding 5,269 fathoms, about six statute miles. The "Challenger" explorations give no support to the fanciful theory of a lost "Atlantis." Microscopic investigations have revealed no traces of mythical continents now beneath the sea.

(3). The determination of oceanic temperatures and their independence of seasonal variation below the depth of 100 fathoms.

(4). The proof of constant bottom temperatures over large areas in the ocean. Thus, in the N. Atlantic the temperature at depths exceeding 2,000 fathoms was found to be constant at about 36·5° F., while in the N. Pacific the bottom temperature was constant at 35° ; in parts of the S. Atlantic the temperature at the bottom fell to 32·7°, while in the Sulu Sea it is 50·5°, and in the Arafura Sea 38·6°, while it is known that the bottom temperature of the Mediterranean is constant at 55·5°, and that of the Red Sea at 69°, these differences being due to certain oceanic areas being separated from each other by submarine ridges, which prevent a more general spreading of the cold bottom water from the poles. No bottom temperature was obtained as low as the freezing point of salt water.

(5). The determination of the exact position of many islands and rocks, the longitude of which had been previously uncertain.

(6). The charting and surveying of various little known parts of the world, and their biological investigation.

(7). The determination of the ocean currents both on the surface and at various depths.

One of the results of the "Challenger" expedition was undoubtedly an increase in our knowledge of the details of structure and the probable mode of formation of coral reefs and islands. Before the expedition, several geologists and naturalists had published doubts as to the universal applicability of the subsidence theory of coral reefs which we owe to Darwin. Semper, for example, showed that in the Pelew Islands up-raised reefs and atolls (which according to the theory indicate a sinking area), are found close together. The "Challenger" observations in regard to submarine elevations and the mode of accumulation of deep sea deposits enabled Mr. Murray (afterwards Sir John) to formulate and publish a new theory as to the origin of atolls, which does not postulate any changes of level, but makes use merely of processes of growth and decay which we know to be at work and constantly acting. The matter is by no means finally settled even now, and it may well be that Darwin's theory holds good in certain parts of the ocean while Murray's explanation is true for other series of atolls.

One of the principal additions to knowledge made by the "Challenger" observations was as regards the deposits now accumulating at various depths on the floor of the ocean. During the voyage the preservation and examination of these deposits was part of Murray's work, and subsequently, along with his friend the Abbé Renard, he made a most comprehensive study of all the submarine deposits (about

12,000) that could be obtained from various expeditions, and published in the "Challenger" series a most authoritative report, which will be for long the standard work on the subject. Omitting terrigenous deposits, which are formed close to the shore and are made up chiefly of matters washed down from the land or worn off from the coast, the deep-sea "oozes," as they have come to be called, are divided into various kinds, such as Globigerina ooze, Radiolarian ooze, Diatom ooze, Pteropod ooze, according to the nature of their chief constituents, while another most extensive deposit, occupying over 50 million square miles on the floor of the ocean at depths of over 2,000 fathoms, contains comparatively few conspicuous organisms and is known as Red Clay because of the alumina and iron and manganese which it contains. In some places associated with the Red Clay are found great deposits of manganese nodules, ear-bones of whales, and gigantic sharks' teeth apparently belonging to extinct species. It was the "Challenger" observations that first enabled oceanographers to map out the distribution of these pelagic oozes on the floor of the ocean, and which first gave us a rational explanation of their nature and process of formation.

In connection with deep-sea deposits, it may be appropriate to point out that it was the naturalists on the "Challenger" who pricked the bubble of "Bathybius" and made known the real nature of that mythical organism. Some eminent biologists of the past, from an examination of some of the earlier deep-sea dredgings, had come to the conclusion that a grey gelatinous material, sometimes found in such deposits, was the remains of a primitive protoplasmic living slime covering the ocean bottom as a nutrient pabulum upon which, in the absence of plants, the more highly organised animals could graze—reminding one of the good old days in Ireland when—

"The streets of Kilkenny were paved with penny loaves,
And the houses were thatched with pancakes."

In his book "The Depths of the Sea," Wyville Thomson speaks of it as "the universally distributed Moner of deep water," and gives an excellent figure of it with its amoeboid protoplasm and its contained Coccoliths.

The Bathybius myth had for a time a great vogue—particularly in Germany. Theoretically it was beautiful, it explained so much, but unfortunately on the "Challenger" it came in contact with hard facts of experiment and at once succumbed. It was proved that when a certain quantity of strong alcohol was added to a certain quantity of sea-water, the sulphate of lime was precipitated in the form of an amorphous deposit which clung around any particles, such as sand grains, mud, or the minute shells of an ooze, and gave exactly the appearances under the microscope which had been supposed to indicate the presence of protoplasm in the submarine deposit. Thus, as Huxley once said, "Bathybius has not fulfilled the promise of its youth," but from the experiments of the "Challenger" naturalists has been shown to be simply the sulphate of lime in the sea-water of the ooze precipitated by the alcohol which was added for preservation purposes.

There were great and widespread hopes and expectations amongst scientific men that the "Challenger" explorations would result in the discovery of many ancient and primitive types, belonging to extinct groups, still living in the great depths of the ocean. These hopes were not realised to any great extent. No Trilobites, no Cystoids and Blastoids, no archaic connecting links comparable in morphological importance with such land or shallow water forms as *Ornithorhynchus*, *Amphioxus*, *Balanoglossus*, *Peripatus*, *Apus* or *Limulus* have been found in the depths of the ocean; and the accepted view now is that the deep sea animals are not for the most part early and primitive forms, but have been derived from the more ancient shallow water faunas. There are comparatively few "living fossils" in the deep sea. The vast number of new forms, however, added greatly to our knowledge of the infinite variety and range of structure of almost all groups. The expedition conclusively established the existence of abundance of living things, from the lowest of marine animals up to fishes, in even the great abysses of the ocean.

If we make a careful survey of the fifty large quarto volumes of Reports, we find that most of the innumerable discoveries, with which the "Challenger" expedition has enriched Zoological science, are additions to our knowledge, either of the abyssal animals that live at the bottom of deep water, or of the plankton, those that float near the surface. Beginning with the lower animals and working upwards, in the Radiolaria Haeckel, who reported on the material, made known more than 4,000 species, for the most part new to science. The numerous beautiful plates of the organisms forming Radiolarian and Globigerina ooze are amongst the most important additions to our knowledge of the Protozoa. A wholly new group of Radiolaria, the Challengerida (Phæodaria), having a remarkable skeleton of hollow spines formed of a peculiar combination of silica with organic matter, and living in intermediate waters at a considerable depth but not on the bottom, was added by the "Challenger" investigations.

Literally hundreds of new species of Sponges were described in the "Challenger" Reports, and amongst these the greatest interest attaches to the representatives of that ancient and wonderfully beautiful group, the Hexactinellida, in which we find *Euplectella*, the "Venus' flower basket" of the Philippine Islands, and *Hyalonema*, the "glass rope" sponge.

In the Coelenterata the work of greatest novelty and distinction was certainly that of the late Professor Moseley. His remarkable report on "Corals" contains a section on the Hydrocorallinæ, which is full of original discoveries of great value which have now been incorporated in all text-books of Zoology. He confirmed the view that *Millepora* is a stony Hydroid, and he was able to prove that all the Stylasteridæ also belong to that group, and incidentally his work overthrew the old-established group of the Tabulate Corals. In another section of this report he gives an account of the important discovery, which he made at the Philippine Islands, that *Heliopora*, the blue coral, is really an Alcyonarian.

Amongst the Echinoderm reports, that on the Crinoidea is perhaps the most interesting and important. It may be recalled that it was the discovery by G. O. Sars in 1864 of the stalked Crinoid, *Rhizocrinus*, a member of the Jurassic and Cretaceous family Apiocrinidae, still living in the deep fjords of Norway, that stimulated Sir Wyville Thomson and Dr. W. B. Carpenter to promote the cruises of the "Lightning" in 1868, and of the "Porcupine" in 1869 and 1870, and thus led up to the "Challenger" expedition. Sir Wyville had intended himself to describe the stalked Crinoids, and had made some progress in the examination and classification of the specimens and in the preparation of some of the plates when his break-down in health prevented any further work of the kind. The reports on these and on the Comatulida were eventually prepared by Dr. Carpenter's distinguished son, Dr. P. H. Carpenter, who as a lad had been his father's assistant on one of the cruises of the "Porcupine." The "Challenger" results definitely showed that, in place of being as was supposed "a group on the verge of extinction," the stalked Crinoids were widely distributed and showed scarcely any decrease in numbers since the times of their ancestors in Mesozoic seas. Some of the Echinoidea described in the report by Professor Alexander Agassiz resemble the Ananchytidae of the Chalk, others are related to the extinct *Galerites*; while *Cystechinus*, with a thin flexible test, recalls the Palaeozoic Palæechinidae. Some of the Echinothuridae, with flexible tests of imbricating plates, had long been known as Cretaceous fossils, and the first-found living representative, *Calveria hystrix*, of the " Porcupine," was added to on the " Challenger " expedition by various species of the remarkable allied genera, *Phormosoma* and *Asthenosoma*.

Many abyssal star-fishes of primitive type were found, and a number of these, in place of passing through a free larval stage, have " direct " development, and keep their young for a period in some form of nidamental pouch. Many new and extraordinary deep water Ophiuroids were added to knowledge, but it is perhaps in the Holothurians that we find the most surprising novelties. A whole new abyssal group of over fifty remarkable species—the Elasipoda—has been made known in the report by Professor Hjalmar Théel, nearly all found at depths greater than 1,000 fathoms and ranging practically from pole to pole. They are characterised, partly by primitive characters, such as the open madreporic canal on the surface of the body, and partly by adaptive characters fitting them to a life on the bottom ooze, over which they crawl and upon which they feed.

Amongst novelties in the Worms may be noted an elaborately branched *Syllis*, spreading its numerous ramifications through the canal system of a Hexactinellid Sponge dredged off the Philippines. Another noteworthy form was *Pelagonemertes*, a pelagic Nemertine described by Moseley, from the North Pacific and the Southern Ocean.

The " Challenger " Reports on Crustacea occupy nearly one fourth of the whole, and describe nearly 1,000 new species, some of which show remarkable modifications induced by life at great depths. Certain of them are totally blind, and others have eyes that are profoundly degenerate in their minute structure and are probably useless as organs of sight.

Amongst the Pycnogonida, or Sea-Spiders, were some gigantic forms of *Colossendeis* measuring about 2 feet across the out-stretched appendages. Although not, of course, a discovery in Marine Biology, it may be noted here that Moseley was enabled, by the examination of fresh specimens of *Peripatus* obtained at the Cape, to demonstrate the essentially Tracheate nature of that primitive and annectant form. Living representatives of the fossil Trilobites were eagerly looked for—but never found.

In the Mollusca, as in Crustacea, we find a tendency for the eyes to degenerate or disappear, in deep water. The "Challenger" collections enabled Pelseneer to establish a phylogenetic classification of the Lamellibranchiata based on the structure of the gills, and to show that the pelagic Pteropods are a polyphyletic group, some of which are related to one, and the rest to another, section of the Opisthobranchiata. One of the prizes obtained was the living specimens of *Trigonia*, dredged off the coast of Australia, a primitive cockle-like form found fossil in European rocks of secondary age, and long supposed to be extinct.

In the Cephalopoda the single specimen of *Spirula*, of which only five individuals are known to science, is one of the priceless treasures of the expedition. A living *Nautilus pompilius* was brought up from 320 fathoms, off Fiji, and Moseley has given us a description of its swimming movements in a tub of water on deck. It had been confidently hoped that some deep-sea representatives of those extinct groups, the Ammonites and Belemnites of Mesozoic times, would be found, and Moseley tells us that "even to the last every cuttle-fish which came up in our deep-sea net was squeezed to see if it had a Belemnite's bone in its back"—all in vain—no such "living fossil" was found.

One of the greatest discoveries of the "Challenger" expedition was the remarkable *Cephalodiscus*, dredged in the Straits of Magellan from 245 fathoms. It is a gregarious member of the Hemichordata related to *Rhabdopleura* and *Balanoglossus*, and it buds off new individuals which all live together in the cavities of a hollow gelatinous coenoecium, which they have jointly secreted. Dr. Harmer has shown that the regions of the body and the divisions of the coelom correspond closely with those of *Balanoglossus*, and that there is a tubular notochord extending forwards from the pharynx to strengthen the proboscis region.

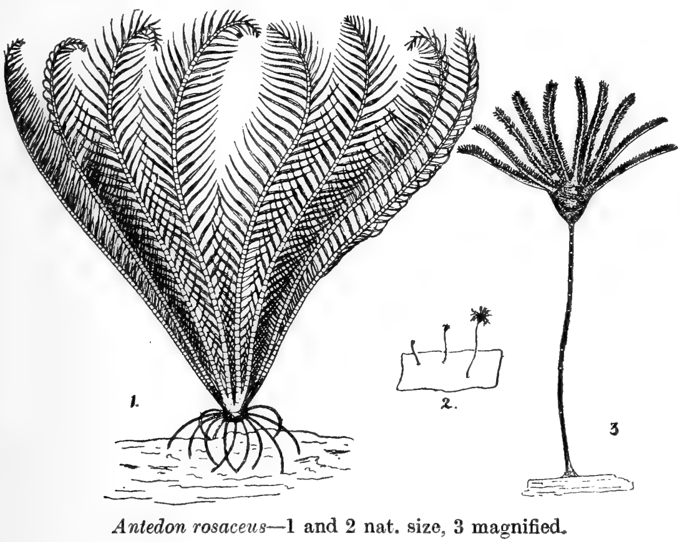
Amongst the Tunicata many remarkable new abyssal forms were obtained, which have added greatly to our knowledge of the range of structure in the group. For example, the new genus, *Octacnemus*, first described by Moseley, has a much reduced and degenerate branchial sac, and has required the formation of a new family. Then, again, several distinct genera, *Pharyngodictyon* amongst Compound Ascidians, and *Culeolus*, *Fungulus* and *Bathyoncus* amongst Ascidiae Simplices, have the branchial sac simplified by the total absence of the system of fine inter-stigmatic vessels, the result being that the wall of the organ is reduced to a net-work of very large meshes, in most cases strengthened by branched and curved calcareous spicules. These are all of them abyssal forms, and no such structure of the branchial sac has been found in shallow water Ascidians. Very many of the deep-sea Ascidians, including the new genera *Culeolus*, *Fungulus*, *Ascopera*, *Hypobythius* and *Corynascidia*, are pedunculated, as if they required to be supported upon stalks above the soft ooze in which their bases are entangled and upon which the animals evidently feed. The intestines are found distended with, in some cases, Globigerina and, in others, Radiolarian or Diatomaceous ooze. Amongst pelagic Tunicates a noteworthy form is a new *Pyrosoma* of gigantic size, of which a magnificient specimen, measuring over four feet in length, was obtained in the North Atlantic, but of which unfortunately, only fragments were preserved. Moseley, in his delightful book, "Notes by a Naturalist," tells us that the officers amused themselves by writing their names with the finger on the surface of the giant Pyrosoma, as it lay on deck in a tub at night, and the names came out in a few seconds in letters of fire.

Many interesting discoveries were made on the "Challenger" in regard to the deep-sea fishes, which were shown to extend down to no less than 2,750 fathoms. Perhaps the most sensational novelty is the presence of light-producing organs on the heads, gill-covers, and bodies of many abyssal fishes, and apparently under the control of the animal's will. Delicate organs of touch are in other cases associated with imperfect eyes. All the deep-sea fishes are, however, modifications of shallow water forms, and none of them represent types of earlier date than the Cretaceous period.

No reference can be made here to the valuable reports on Reptiles, Birds, and Mammals—nor to those on the Botany and Anthropology of the various little-known lands visited during the expedition.

I am afraid that I have been able to give only a brief and inadequate summary of some of the chief results of the "Challenger" expedition, but I must not omit to point out that one of the most important results is the improvement in methods of investigation seen in later expeditions. It is easy to criticise the "Challenger" equipment and methods, and even the contents of some of the reports, but it must be remembered that it all happened a generation ago and that the methods of science may become old-fashioned in a very few years. The Naturalists on the "Challenger" were the pioneers of deep-sea exploration, and their experiences taught many lessons by which later expeditions profited. Improved methods of capture of oceanic animals have resulted from the uncertainty felt on the "Challenger" as to the zone from which particular organisms found in the nets had been really obtained. Instruments, invented since, that can be opened and closed at any given depth will prevent, or at least minimise, any such possible errors in the future. Wire has been substituted for rope in both sounding and dredging, and all the physical and chemical apparatus and methods are now much more reliable and refined than those employed by the "Challenger" pioneers. This is merely the natural result of the progress of science, and especially of such a new and rapidly advancing science as Oceanography, during forty years of strenuous endeavour.

Some of the "Challenger" reports may be found old-fashioned and unsatisfying in transcendental morphology by the student of the present day, but the fifty noble volumes form a zoological library in themselves, and every young specialist on a group of marine animals has still to consult them, and before proceeding to new and no doubt more profound researches must ascertain what was made known by his predecessors from their work on the collections brought home from the abysses of the ocean by the "Challenger" circumnavigating expedition.



Antedon rosaceus—1 and 2 nat. size, 3 magnified.

Appendix B.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1916).

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., 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., London.

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.

LIVERPOOL MARINE BIOLOGICAL STATION AT PORT ERIN.

General Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biology 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 steamboat 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 prepare a short report upon his work—not necessarily for publication—to be forwarded to Prof. Herdman before the end of the year for notice, if desirable, in the Annual Report.

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.

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 in the living state, 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.

REGULATIONS OF THE EDWARD FORBES EXHIBITION.

[Extracted from the *Calendar* of the University of Liverpool for the Session 1915-16, p. 438.]

"EDWARD FORBES EXHIBITION.

"Founded in the year 1915 by Professor W. A. Herdman, D.Sc., F.R.S., to commemorate the late Edward Forbes, the eminent Manx Naturalist (1815-1854), Professor of Natural History in the University of Edinburgh, and a pioneer in Oceanographical research.

The Regulations are as follows :—

(1) The interest of the capital, £100, shall be applied to establish an Exhibition which shall be awarded annually.

(2) The Exhibitioner shall be a post-graduate student of the University of Liverpool, or, in default of such, a post-graduate student of another University, qualified and willing to carry on researches in the Manx seas at the Liverpool Marine Biological Station at Port Erin, in continuation of the Marine Biological work in which Edward Forbes was a pioneer.

(3) Candidates must apply in writing to the Registrar, on or before 1st February.

(4) Nomination to the Exhibition shall be made by the Faculty of Science on the recommendation of the Professor of Zoology.

(5) The plan of work proposed by the Exhibitioner shall be subject to the approval of the Professor of Zoology.

(6) Should no award be made in any year, the income shall be either added to the capital of the fund, or shall be applied in such a way as the Council, on the recommendation of the Faculty of Science, may determine.

(7) The Council shall have power to amend the foregoing Regulations, with the consent of the donor, during his life-time, and afterwards absolutely; provided, however, that the name of Edward Forbes shall always be associated with the Exhibition, and that the capital and interest of the fund shall always be used to promote the study of Marine Biology."

Edward Forbes Exhibitioners.

1915 Ruth C. Bamber, M.Sc.
1916 E. L. Gleave, M.Sc.

Appendix C.

HON. TREASURER'S STATEMENT.

In the following pages are shown the Balance Sheet and list of subscribers.

There is a small balance in favour of the Committee, but unfortunately the receipts have been reduced. As was to be expected, there have been fewer visitors to the Aquarium, and the sale of Guides has consequently diminished.

We received a grant of £50 from the Board of Agriculture and Fisheries for Research work, but more than this amount has been spent during the year; there is still, however, a balance in hand which will enable this work to be carried on next year.

Edwin Thompson,
Hon. Treasurer.

25, Sefton Drive,
Liverpool.

December 14*th*, 1916.

SUBSCRIBERS.

	£	s.	d.
Browne, Edward T., M.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., 43, Harrington Gardens, London, S.W.	2	2	0
Brunner, Roscoe, Belmont Hall, Northwich ...	1	1	0
Clubb, Dr. J. A., Public Museums, Liverpool ...	0	10	6
Cole, Prof., University College, Reading	1	1	0
Dale, Sir Alfred, University, Liverpool	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ...	2	2	0
Gibson, Prof. R. J. Harvey, The University, Liverpool	1	1	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
Holt, Dr. Alfred, Dowsefield, Allerton	1	0	0
Holt, Mrs., Sudley, Mossley Hill, Liverpool ...	2	2	0
Isle of Man Natural History Society	2	2	0
Jarmay, Gustav, Hartford, Cheshire	1	1	0
Livingston, 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
Monks, F. W., Warrington...	2	2	0
Muspratt, Dr. E. K., Seaforth Hall, Liverpool ...	5	0	0
O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool	1	1	0
Forward	£43	16	0

	£	s.	d.
Forward... ...	43	16	0
Petrie, Sir Charles, Ivy Lodge, Aigburth, Liverpool	1	1	0
Rathbone, Miss May, Backwood, Neston	1	1	0
Rathbone, Mrs., Green Bank, Allerton, Liverpool	1	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
Ward, Dr. Francis, 20, Park Road, Ipswich ...	2	2	0
Watson, A. T., Tapton-crescent Road, Sheffield ...	1	1	0
Whitley, Edward, The Holt, Linton-road, Oxford	2	2	0
Yates, Harry, 75, Shudehill, Manchester	1	1	0
	£66	5	0
Deduct Subscriptions still unpaid *less* old Subscriptions received	9	11	0
	£56	14	0

SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
University College, Reading	2	2	0
	£32	2	0

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

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

1916.	£	s.	d.
To Printing and Stationery	14	14	2
,, Boat Hire	5	0	0
,, Books, Apparatus and Supplies at Port Erin Biological Station	11	12	9
,, Postage, Carriage, &c.	3	6	2
,, Salary—Share of Curator's	85	0	0
,, ,, ,, Assistant's	22	17	3
,, Sundries	4	16	4
,, Balance in Hand, December, 1916	10	10	4
	£157	17	0

Endowed Invested Fund:—
British Workman's Public House Co. 90 Shares £1 each fully paid.

EDWIN THOMPSON,
HON. TREASURER.

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

LIVERPOOL, *December 14th, 1916.*

1916.	£	s.	d.
By Balance in hand, December, 1915	13	3	3
,, Subscriptions and Donations received	56	14	0
,, Amount received from Universities for hire of "Work Tables"	32	2	0
,, Laboratory Fees	2	0	0
,, Interest on British Association (1896) Fund	31	10	0
,, Sale of Guides and Post Cards	5	7	11
,, ,, Specimens, Bottles, &c,	1	5	6
,, Bank Interest	15	14	4
	£157	17	0

	£	s.	d.
Memoir Fund—Balance, as at December, 1915	£185	0	1
Extension Fund:—Balance, as at December, 1915	£37	4	9
Board of Agriculture and Fisheries Account—			
Balance December, 1915	275	0	0
Grant for year 1916	50	0	0
	325	0	0
Research Work Expenditure	82	7	0
	£242	13	0

REPORT ON THE INVESTIGATIONS CARRIED ON DURING 1916 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.

CONTENTS. PAGE

1. Introduction 77
2. Summary of Work at the Piel Laboratory. By A. Scott ... 82
3. Summary of Work from the Liverpool Laboratory, on Shell-fish Cultivation, &c. By J. Johnstone 89
4. Summary of Intensive Plankton Work. By W. A. Herdman, A. Scott, and H. M. Lewis 104
5. The Exploitation of Inshore Fisheries. By W. A. Herdman ... 107

INTRODUCTION.

In accordance with the wishes of the Committee, as expressed in their Minute of 18th November, 1915, I once more submit an abbreviated form of Report giving merely a summary of the scientific work in connection with Sea-Fisheries investigations which it has been possible to carry on during the past year under War conditions, reserving the detailed observations, the tables of statistics, diagrams, curves and charts with which these Annual Reports have usually been illustrated to be produced on some future occasion, when more normal work has been resumed in our District.

Staff.

Our depleted Scientific Staff has undergone no further change since last year ; but I much regret to have to record the death in hospital of our former much esteemed Laboratory Assistant, Thomas Hampson, who had given excellent service during a number of years, at first in the Zoological Department of the University, and latterly in the Sea-Fisheries Laboratory. After being twice rejected on medical grounds, Hampson enlisted in 1915, as an hospital orderly, and was for some time engaged in the Pathological Laboratory of the University, in the preparation of the necessary materials for the bacteriological investigation of the cases in the Military hospitals of the district. He was afterwards transferred to the Fazakerley Military Hospital, but was evidently unable to withstand the strain of the necessarily hard work. An old-standing constitutional weakness of the lungs reappeared, and after an illness of some weeks he died in the Royal Infirmary, on 27th December, 1916, much regretted by all with whom he had worked. He was a young man of much promise, who gave constant, careful and helpful service, chiefly under Dr. Johnstone's direction in our laboratory, and might, after further training, and under happier conditions in the future have gone on to more important scientific work for the Committee. Our Report for 1914 contained a short paper by Hampson (then known as Monaghan) on the spawning of the shrimps in the Mersey Estuary.

Mr. W. Riddell, M.A., joined the Liverpool Scottish in July last, and is now on active service in the Machine Gun Corps.

Work at Piel.

For reasons which are given by Mr. Scott in his section of the Report, no Fishermen's Classes have been possible, and no fish-hatching has been carried on. Mr. Scott continues the history of the Morecambe Sprat Fishery, which he described in last year's Report, and shows how desirable it is that "curing" of the fresh fish should be established locally. The investigations which he has been able to carry out on Herrings and on Plaice, at the Piel Laboratory, are fully explained and need no comment. The remarkable Roosebeck Plaice fishery of last Autumn, of which he gives an interesting account, is worthy of record.

Shell-Fish Cultivation, &c.

The most important part of this Report is Dr. Johnstone's account of the work carried out under the Committee during the past year in connection with schemes for the improvement of the Shell-fish industries in the neighbourhood. The conclusion, that the result of inspection and bacteriological analysis ought to be the establishment of purification plant and not merely the condemnation of a shell-fish bed, is one of great importance, which will no doubt receive careful and sympathetic consideration. Dr. Johnstone's discussion of the methods of analysis and the nature of the polluting organisms is most instructive, and shows the difficulty in arriving at very definite results.

The opinions given by Dr. Johnstone on the important question how far fishes infested by parasites or suffering from tumours and other diseases are thereby rendered unsuitable for human food, are of wide interest to the general public, and may do something to allay the fears of nervous customers.

Although our biometric scheme of Herring investigation has had to cease for the present, Dr. Johnstone has been able on samples of Manx summer herring, obtained from Port Erin, to examine the fat-contents of the flesh and explain its bearing on the food value of the fish. The suggestion that we should make more use of the fat summer herring cured in brine as a winter food ought, under present conditions, to receive careful attention.

The section on the life-history of the Plaice in our local waters shows how much laborious work has been done which is not now published, but which will be of value some day when we are able to lay it in detail before the Committee.

Plankton Investigation.

Although work out at sea is wholly stopped, the periodic collection of plankton samples in Port Erin Bay, at the South end of the Isle of Man, is one portion of our usual work which it has been possible to continue without alteration. During two important periods of the year, spring (April) and autumn (August and September), I have been able to take very frequent samples from my motor boat, and during the remainder of the year the staff of the Biological Station have collected and preserved periodic gatherings. These have been microscopically examined by Mr. Andrew Scott, at Piel, the results have been reduced to tables and diagrammatic curves by Miss Lewis at Liverpool, and we give a summary of the results in a short article further on in the Report.

Minor Local Fisheries.

I have thought it justifiable to reprint* at the end of this Report a short address on "The Exploitation of Inshore Fisheries," which was read before the British Association at the Newcastle-on-Tyne Meeting, last September. It formed the opening of a day's discussion on the subject of Inshore

* An abstract was published in *Nature* for December 21st, 1916 (p. 317).

Fisheries, in which Dr. Masterman and others from the Board of Agriculture and Fisheries, Professor Meek from the Cullercoats Laboratory (Northumberland), Dr. Allen from the Plymouth Laboratory, and other authorities on the subject took part. It contains some references to work done in the past under our Committee and published in detail in former Reports (such as our Mussel-transplantation experiments in 1903-5), along with more recent examples of the value of well-timed and judicious assistance in stimulating a local fishery, but it may serve a useful purpose to draw attention again to the matter at a time like this when any possible addition to the food supplies of the country is becoming of ever increasing importance.

W. A. HERDMAN.

FISHERIES LABORATORY,
UNIVERSITY OF LIVERPOOL,
February 5th, 1917.

SUMMARY OF THE WORK AT PIEL.

By Andrew Scott, A.L.S.

I. Classes at Piel.

In view of the difficulty in getting suitable men, no classes for fishermen were held in the spring of 1916. The majority of the deep-sea fishermen are engaged on Government work. The few that are left to carry on fishing operations would probably not have been able to find substitutes to take their places on board ship, and so allow them to get away. Many of the inshore men have gone into the large shipbuilding and other works in their districts.

We have had occasional visits from members of the crews of mine-sweepers whose duty brought them into this harbour. The men were either former members of the classes or had heard about them from those who had been present. The men who had not been students expressed the hope that the biology and navigation work would be resumed when circumstances again became favourable, and that they would have an opportunity to attend.

One of the points some of these visitors were anxious to have cleared up was whether the time spent mine-sweeping, &c., would count when entering for their trawling certificates. I happened to be writing to Captain Thornber at the time and brought the matter before him. He replied that the Board of Trade had decided that the time spent by fishermen in any of His Majesty's Services afloat or ashore, and even in the armies, would be regarded as sea time when filling up the application forms for examination. This information was forwarded to the addresses left by the men and duly acknowledged.

II. Fish Hatching.

For the reasons mentioned in last year's report no hatching operations were carried on in 1916. The engine, pumps, and hatching apparatus have been meanwhile kept in good condition to begin work when the time arrives.

III. Distribution of Fish Eggs in the Plankton.

Our knowledge of this subject in 1916 was again restricted to what can be gained from the bi-weekly collections in Port Erin Bay and its neighbourhood. There were examined 496 samples, and a good deal of additional information has been secured which will be available for publication later on. The number of collections examined in 1915 was 320. The total for the period of ten years now completed, which was regarded as a minimum time for this investigation, is 5,116.

IV. Morecambe Sprat Fishery.

This winter fishery appears to be firmly established now, and preparations to participate in it are made well in advance of the time when the fish are expected to be abundant. No alteration has been made in the fishing apparatus which was fully described in the report for 1915. Some of the fishermen who, in previous winters, engaged wholly in musselling found it more profitable to fit out their boats for sprat fishing in the winter of 1916.

The season opened about the middle of October. The fishery did very well for a time, and from 6 to 10 half-hundred-weight boxes per boat were landed for some days. The weather during November was very stormy and generally unfavourable. The result was that the catches became so small that the fishermen began to be afraid the season would be a failure. The rough weather has evidently a tendency to break up and scatter the shoals of sprats in the shallow water where the work is carried on. A favourable change in the weather conditions took place in December, and frost set in with very little wind. This allowed the fish to congregate, and large catches began to be reported. Some of the boats were landing nearly 100 boxes each by the middle of December. Temporary packing houses were established so that the catches could be more rapidly dealt with. There the fish were gone over and packed into boxes for despatch by rail to various centres where a certain amount of curing has been done in the past. In conversation with the men, one finds that the general expression with regard to the fishery now is the hope that curing houses will be established in Morecambe in the near future. This is a matter that depends largely on themselves. Some of the more enterprising may yet take the matter up and perhaps be able to do so with slight financial assistance from the Government. The sprats could then be cured immediately on being landed instead of having to be sent away fresh to distant places for that purpose, as at present.

The condition of the fish caught in 1916 was similar to our previous experiences. A few small herring and half-grown whiting were present in every haul. These whiting are attracted by the food supply in the shape of shoals of sprats, and have to be removed by the packers. The more rapid decomposition of the whiting would soon spoil the condition of the sprats if left amongst them. The stomach of every whiting examined was tightly packed with sprats in various stages of digestion. In some cases the half of a freshly captured sprat was even projecting out of the whiting's mouth, notwithstanding the fact that the stomach was already filled.

Estimations of the oil and water contained in the muscle substance were made in mature sprats and immature herring of nearly similar size. The results show that in the case of the sprats the oil amounted to 11·10 per cent., and the water to 73·76 per cent. In the herring the amount of oil present was 2·61 per cent. and 80·27 per cent. of water.

V. Food of Port Erin Herring.

Three stomachs from a sample of herring landed at Port Erin on July 5th, 1916, were sent to me for examination by Dr. Johnstone. The following are the results :—

No. 1 and No. 3.	No. 2.
Calanus finmarchicus, common.	*Calanus finmarchicus*, rare.
Candacia armata, 1 only.	*Candacia armata*, 1 only.
Larval decapods, a few.	*Meganyctiphanes*, a few.
,, schizopods, a few.	Larval decapods, rare.
Young clupeoid, remains.	,, schizopods, common.

VI. Whitebait Collected in Menai Strait.

This investigation on the material collected by Capt. R. Jones is being continued. In my report for 1914 on this subject it is suggested that there is a forward movement of the dorsal fin in early stages of these young clupeoids. A more careful analysis of the various measurements of the dorsal and pelvic fins has recently been made. The new results indicate that the displacement takes place in the pelvic appendages and not in the dorsal fin in the case of the sprat, and in the dorsal fin in the case of the herrings. At a certain limiting age the forward movement of the dorsal fin in the herring ceases.

VII. Roosebeck Plaice Fishery of 1916.

The plaice fishery at Roosebeck in the autumn of 1916 will probably long be remembered by the stake-net men for its abundance and extraordinary money value. The late

Mr. John Fell used to tell us of the great stake-net fisheries of a quarter of a century ago when the men were often unable to cart away the whole of the catch. Vast quantities had to be left to decompose in the nets, and the men could not be persuaded to take the nets down to prevent so much waste. Prices then were low, an abundance of fish tended to still further lower the market value until it became unprofitable to take the catches away. The prices offered in 1916 by the local dealers were astonishingly high, and the men had no difficulty in disposing of every catch owing to the keen competition. No fish were left in the nets to be wasted.

Expectations of an autumn stake-net fishery were raised when an immense visitation of plaice was discovered on the rough ground just outside Barrow Channel, early in July. Owing to the restrictions, none of the local trawlers could go out to trawl in this area, and the fishing was left to boats from more distant ports. Seventeen to thirty second class trawlers from Morecambe and Fleetwood fished over the area as the weather and tides permitted during the next three months. The rough ground did considerable damage to the fishing gear at times, but the boats on the whole did very well. Some of them landed up to 50 score pounds—nearly half a ton—as the result of the day's fishing. The general average is reported to have been between 25 and 30 score pounds per boat per day.

The shoal of plaice gradually made its way further along the shore, and by September had reached the area where the stake nets are set at Roosebeck. These nets can only be profitably employed during spring tides as they do not ebb dry at low water of neap tides. This fishing is therefore intermittent, and generally lasts from seven to ten days out of each fortnight. Good catches were made in the period 11th to 17th September, but these were far exceeded by the results of the second period, September 25th to Oct. 1st. One fisherman employing six nets captured 68 score pounds, or over half a ton, on September 28th. Another with nineteen nets captured over 200 score pounds, or nearly two tons, of plaice on September 29th. The plaice were so abundant at this particular period that large catches were taken even during the day tides, when low water was in the late afternoon between 5 and 7 p.m. The fishery diminished very much in value after the middle of October owing to the continuance of strong winds which drove the fish further up the bay. A succession of southerly and westerly gales in November set up heavy seas which broke down the stakes and in many cases completely wrecked the nets. The quantity of plaice captured in the stake-nets at Roosebeck in the last four months of 1916 amounted to nearly 3,000 cwts.

Samples of the plaice were secured at frequent intervals so that they could be measured, weighed and examined for the age and sex conditions. The size ranged from 18 cm. to 48 cm. The majority of the plaice were between 23 cm. and 27 cm. Quite a number of the larger sizes of over 30 cm. were mature fish which would certainly have reproduced in the spring of 1917. The largest one examined measured 48 cm., nearly 19 inches in length. It weighed 1,407 grammes = 3 lbs. 1·6 oz., and was a female with the ovaries well developed. The age as indicated by the otoliths was $n + 5$ (six years). The stomach and intestines of every plaice examined were filled with broken mussel shells, showing that the fish were feeding exclusively on the young mussels which were then covering the beds near where they were captured. Previous to this invasion of plaice, the beds were stocked with mussels between 10 mm. and 20 mm. long. Very few mussels were left when the fishery ended.

In pre-war days the Roosebeck fishermen usually received 2s. 6d. per score pounds for their plaice. When the price happened to reach 3s. 0d. per score pounds the fishermen considered they were doing well. The price per score pounds during the fishery of 1916 varied from 7s. 6d. to 10s. 0d. in August, September and October, and to 14s. 0d. in November. This sum was clear profit, as it was exclusive of railway carriage. The increase in price compared with pre-war times was not due to the fishermen's avariciousness. It was largely owing to the competition amongst the dealers to get hold of the supplies, and the fishermen were naturally quite pleased to be so well paid. The increase in the cost of production does not arise here, as most of these stake-net men have small farms along the coast adjacent to the fishing area. Fishing with them is really a side line which may be very profitable sometimes. The Roosebeck plaice were sold to the public in the local fishmongers' shops at from 6d. to 9d. per pound according to size. There does not appear to be much economy in buying the smaller sizes as the loss involved in preparing them for cooking is considerable, as shown by the following table:—

Loss in weight due to removal of fins, tail, head and gut.

Size	20 cm.	Loss	24	grammes	= 32 %	of	original	weight.
,,	25 cm.	,,	55	,,	= 30·5 %		,,	,,
,,	26 cm.	,,	54·3	,,	= 30·4 %		,,	,,
,,	27 cm.	,,	62	,,	= 28·3 %		,,	,,
,,	28 cm.	,,	77·5	,,	= 27·5 %		,,	,,

Then, of course, the food value is further reduced by the weight of bone and the amount of moisture present in the muscles.

Amongst other fish captured in the stake-nets beside plaice was a large conger eel, 8 feet 1 inch in length, with a girth of 36 inches and weighing 87 pounds. It was exhibited for a time in one of the Barrow fishmongers' shops at a charge of 1d. per visitor. The resulting income was handed over to the Y.M.C.A. Hut Fund.

SUMMARY OF WORK FROM THE LIVERPOOL LABORATORY.

By James Johnstone, D.Sc.

Shell-fish and Sewage Investigations.

Only brief reference can be made to the various inspections, analyses, &c., that have been undertaken during 1916.

The Mussel Fisheries.

The Barmouth mussel purification tank was completed in September, 1916. Serious difficulties were encountered, and so far the tank has been worked in a provisional manner only.

In October a visit was made, and a series of experiments were made to test the tank. I regard these as successful since a considerable amount of cleansing took place. Nevertheless, these were to be regarded as laboratory experiments carried out with all care. The real test of the efficiency of the tank is the results obtained by the actual working process carried on by the fishermen themselves. This has not yet been satisfactory.

Inspection by the Board of Agriculture and Fisheries.

Dr. Jenkins and I met Dr. R. W. Dodgson, the Board's Bacteriologist, at Barmouth, in November, 1916, and had a conference as to the best way of working the tank. Later in the year I met Dr. Dodgson at Conway, and saw the methods of purification employed there under the supervision of the Board. The experience obtained at Conway has been most valuable, and we are greatly indebted to Dr. Dodgson for many suggestions and much sound advice.

Certain structural modifications of the Barmouth tank were suggested by Dr. Dodgson and are being adopted; and, so far as the difficult local conditions admit, the Barmouth tank is being worked on the lines indicated by the Board's installation at Conway.

The Aberdovey Tank.

The original scheme for the construction of this tank has had to be abandoned because of objections urged by the Royal National Lifeboat Institution, and new plans have been prepared to meet these objections. The choice of suitable sites for a tidal tank at Aberdovey is very limited on account of the difficult nature of the foreshore, and we are practically restricted by the Board of Trade to a site that is not the best. It is hoped that the plans now under the consideration of the Board of Trade may prove workable. Several inspections have been made at Aberdovey, and a conference between officials of the Board of Trade, the Royal National Lifeboat Institution and this Committee was held late in the year. Analyses and tidal observations were made and are being continued.

Lytham Mussel Beds.

The mussel beds at Church Scar, Lytham, were inspected by Dr. Jenkins and myself, and samples were taken for analysis. The condition of the mussels on this scar is not satisfactory.

Barrow and Lune Channels.

After a great deal of discussion, and after two enquiries held under the Shell-fish Regulations, the question as to the mussel purification schemes of the Lune Estuary has been dropped—partly, no doubt, because of the increasing difficulty of maintaining the sanitary services, and partly because the musselling industry in this locality has greatly depreciated. Several series of analyses have, however, been made.

For some reason or other attention was drawn to the condition of the water of the Lune Estuary. Analyses were made in June, 1916, and these showed that the pollution of the Estuary had notably increased.

The pollution of Barrow Channel was also studied. In 1908 Mr. Scott and I sampled the water there throughout one day at intervals of two hours. At about low water we found the degree of pollution was about 200 to 1,000 sewage organisms per cubic centimetre.

In May and June, 1916, Mr. Scott sent me numerous samples of water from the same place, and I found that all of these were sterile (so far as sewage organisms were concerned) in 1 c.c. But we suspected that sewage organisms contained in sea-water undergo diminution when the water is kept long before analysis, and further samples were therefore taken and analysed within half an hour after collection. The mean number of sewage organisms was about 6 per c.c. This remarkable condition was observed at a time when the population of Barrow-in-Furness was abnormally large—augmented by the great influx of munition workers. Doubtless it is due to local, military, sanitary administration.

Other Inspections and Analyses.

Some other cases of mussel pollution—at Heysham and at West Kirby, in Cheshire—have also been examined.

Methods of Analysis and Standards.

As time goes on bacteriological examination of polluted mussels becomes a matter of more and more difficulty, and it would, perhaps, be advisable to lay little stress on the results were it not that the general practice of local health authorities compels us to have recourse to analyses. There is still no recognised "standard of impurity," and one cannot say that it is desirable that there should be such, for it is highly probable that the establishment of a quasi-legal standard of bacteriological impurity would only lead to administrative absurdities and do no real good.

In any particular case what is now the object of inspection and analysis ought to be the establishment and satisfactory working of purification plant, and not the official condemnation or approval of any particular shell-fish laying. And this is really implied in the Shell-fish Regulations. But there is no other method of testing the degree of success of working of a shell-fish purification plant except by bacteriological analysis. What is indicated, or rather what is aimed at, is a considerable reduction of sewage organisms as the result of the process of purification.

The "Bacillus coli" *question.*

As an academic question there can be little doubt as to whether or not any specific sewage organism is or is not that known as *Bacillus coli communis.* But the process of identification is laborious, and generally inapplicable in the actual conditions of routine public health work applied to shell-fish.

In spite of the apparently exhaustive report of the Royal Commission on Sewage Disposal, the question as to what ought to be understood by "*B. coli*" or "coli-like organisms" was left obscure. The large amount of evidence heard by the Commission was out of all proportion to the scanty measure of scientific investigation on which this evidence was based, or which was actually undertaken by the Commission. Therefore there is still conflict of opinion both as to the diagnostic characters of the organisms indicative of dangerous sewage pollution, and as to the standards of impurity—that is, in the routine methods of public health laboratories. There is still no sign that this conflict of opinion is likely soon to be resolved.

The nature of the polluting organisms.

For some time back all sewage organisms isolated from mussels and polluted sea-water have been studied in detail in our laboratory. A provisional report on these results was made in the Annual Report for 1914. Not many organisms can really be studied, as the process of identification is very laborious. Lately the investigation has been necessarily abandoned because of the impossibility of procuring the chemical substances used in the test-media (formerly obtained from the firm of Merck, of Darmstadt).

But even in several hundreds of strains of organisms isolated, at least several dozens of distinct or "particular species" of bacteria were found and less than 5 per cent. of those provisionally called sewage organisms, that is glucose- and lactose-fermenting bacteria, were really *Bacillus coli communis*.

Then the question arises as to what is a "strain" or "particular species" of bacillus, and it is evident that the criteria of "purity of strain," or "identity of species" cannot be the same among the bacteria as among higher organisms, say parasitic worms ; that is, with regard to accepted methods of identification.

It is probable that among the many "particular species" of micro-organisms isolated from mussels, a number of these are of the same significance as regards the possible dissemination of epidemic disease. But it seems probable that the "habits" of these faecal organisms are not identical. Some of them are resistive to changes of environment, and others easily succumb to such changed conditions. Therefore the nature of the mixture of intestinal organisms inhabiting sewage, sea-water or mussels may change very rapidly as one after another of the "particular species" ceases to reproduce and dies out in the new environment. Thus we *ought to be able* to recognise from the nature of a sample of the micro-organisms isolated from mussels or sea-water, what was the probable date of pollution, and therefore the gravity of the pollution from the public health point of view.

But because of the laborious nature of the investigations necessary to give this information, we are not yet able to give such information to the public health authorities with respect to any particular case of pollution. And there is no immediate prospect of this defect of administration being remedied, as it seems to be impracticable to get the requisite investigations made.

The real easiness of purifying mussels.

It is remarkable how very easily polluted mussels may be purified from infected sewage-organisms *in experimental conditions.* The experience of the Board of Agriculture and Fisheries at Conway shows this very clearly. It has become apparent to us several times. In May and June of 1916 I was able to obtain a reduction of nearly one half of the sewage organisms contained in mussels, merely by draining off the water contained in the shell cavities. With a rapid circulation of clean sea-water, even a few hours will cleanse a mussel to all the extent that is necessary.

In my experience mussels received by post for the purposes of analysis are usually cleaner than mussels *from the same spot* which are examined immediately after collection, and this is simply due to the draining away of water from the shell cavities into the vessel containing the shell-fish. In really accurate work the vessel containing the sample ought to be sterilised, and all the mussels in it, as well as the washings from the vessel, ought to be cultivated.

This easiness of cleansing sewage-polluted mussels is, no doubt, satisfactory. But the real difficulties, with which the scientific man has little to do, are the administrative ones. It is of little use recommending and guaranteeing a process of cleansing when one has, unfortunately, every reason to believe that the administrative supervision will be defective and inconsistent with the design of that process.

The further difficulties, at present irremediable, it is feared, are those of cost. In localities such as Conway, where the industry is a large one, relatively expensive plant can be set up and worked. But there are many other localities, such as at Barmouth and Aberdovey, where we have to do with perhaps the produce of a dozen men at the most. Obviously the cost of putting down purification plant must bear some close relation to the value of the local industry.

This difficulty seems capable of removal only by centralisation of the process of cleansing, or perhaps by the adoption of the process as a commercial, profitable one. There seems no reason why the cleansing of sewage-polluted mussels and other shell-fish should not be undertaken by private persons or companies.

Diseased Fish Condemned at the Markets.

Fewer specimens of diseased fish condemned in the fish markets reach the laboratory now, and this is doubtless due to a less rigid inspection than was made before the war. Several instances of malignant tumours—ordinary and melanotic sarcomas, &c., some interesting cases of obscure fungoid infection and some instructive malformations have come to hand and have been investigated.

A question continually asked in such cases is this—What would happen to a person eating such diseased fish? It is, of course, impossible to answer such a question satisfactorily except by trying! In the majority of cases legal proof that the diseased fish in question would be detrimental to the health of the consumer would, I think, be impossible of production.

As a general rule no evil effects are to be apprehended from the consumption of fish containing nematode, cestode, or trematode worms. A case of a codling having the usually occurring nematode worms in the peritoneum occurred. The fish was prepared for food in a military hospital and was refused alike by the patients and by the staff (who ought to have known better). The parasitic worms that usually occur in edible fish do not inhabit the human body. Even if they did, the cooking process would generally destroy them. Such fish should not be condemned.

It cannot be said that the malignant tumours, that is "cancers," of fish are likely to prejudice the health of the consumer. The common-sense way of dealing with such fish is to cut out the part containing the tumour and then to use the rest.

In one case part of a halibut containing "a filthy black substance" was sent to the laboratory. The black substance was a melanotic sarcoma. In some cases these melanotic tumours are multiple and their appearance is forbidding. Rupture of a small tumour of this kind would spoil the appearance of the fish, and no customer seeing such would be likely to buy. But if there is only a single tumour that can be cut away, this should be done and the rest of the fish retained for sale.

A tumour that is malignant and spreads, or sets up secondary tumours, is likely to affect the general condition of the fish. So also with the rather rare cases where the flesh of a fish is extensively invaded by parasite worms, or protozoa. In such cases toxic products may possibly diffuse out from the disordered tissues round the parasites, or from the necrosing (or breaking-down) tumour. These toxic products may enter the blood stream, with the result that the health of the fish suffers, and its flesh becomes emaciated. A fish in such condition is easily recognised by the inspectors, and it ought, in my opinion, to be condemned just as if it were partially decomposed owing to imperfect preservation.

All such specimens are of very considerable scientific interest, and are always fully investigated in the laboratory. Such diseased fishes are always thankfully received, and inspectors and others are requested to forward them whenever found.

Herring Investigations.

The scheme of biometric investigation of local herring races has necessarily been abandoned in the meantime.

Ten samples, of 24 herrings in each, were received during the following months, part of May, June, July, August and part of September. The August samples were cold-stored. The samples came from the Manx summer herring fishery, and were collected and forwarded by Mr. T. N. Cregeen, of the Port Erin Biological Station.

The herrings were examined for :—

Length and weight as an index of "condition";
Condition of the reproductive organs;
Percentage of fat in the flesh.

The samples were too small for biometric investigation.

Length and Weight.

The weight of the herrings, in proportion to their length, rose during the season (with the exception of a singular set-back in June). In September the weight began to fall off. The increase in weight, for herrings of the same length, was due to the increase in mass of the reproductive organs, and to the increase in depth and thickness of the fish, which "had put on flesh."

Course of the Fishery.

The fishery began in May. The herrings were then in Stage I.—virgins or immature, but sexually ripe fish. From then on, the reproductive organs matured. In September all were in Stage VII., except one or two which were either virgins or spent fish. None were found actually spawning (that is, in the samples), and the fishery apparently came to an end before spawning was universal.

The percentage of Fat in the Flesh.

Analyses were made, a part of the muscle substance being taken from each fish in each sample. Males and females were separately analysed.

At the beginning of the season the flesh contained on the average about $2\frac{1}{2}$ per cent. of fat and 75 per cent. of water.

At the beginning of September the flesh contained about 33 per cent. fat and about 47 per cent. water.

At about the end of September the flesh contained about 20 per cent. of fat and about $56\frac{1}{2}$ per cent. of water. Later samples, taken after spawning, would have contained still less fat and more water.

The Food Value.

It is impossible to indicate precisely, as the "food economy" pamphlets and other literature pretend to do, what is the nutritive value of the herring. Winter-caught herring have a very low food value, but summer-caught fish have a correspondingly high value because of their richness in digestible fat. This fat is not massive, but is very thoroughly incorporated among the muscle fibres. Fresh herrings taken in the autumn, winter, and spring months, and sprats taken at the same time are inferior articles of food compared with cured herrings which are taken in the summer months. "Full" herrings are superior articles of food, not only because they contain the proteid-rich roes and milts, but also because they are fish with a high fat-contents.

Fat-rich foods are of course more "seasonable" in winter than in summer, so that the rational practice would be to retain the summer-caught, fat-rich herrings until the cold winter months. This is, of course, done by the process of curing in brine. The salt-curing is also advantageous in that it extracts a certain proportion of the water from the flesh, rendering the latter a more concentrated food stuff. The salting may perhaps increase the actual percentage of fat, but more information is required with respect to this. It also renders the flesh more digestible in that it allows a certain degree of autolysis, that is self-digestion of the muscle substance by the action of the intra-cellular enzymes contained in the tissue. It is possible that the proteid substance so altered sets free fat in some form. The natural process of autolysis, which would go on independently of decomposition due to bacteria, would end in the production of ptomaines, but the salting controls this. The flesh becomes "pasty," and savoury "extractive" substances are formed. This is the rationale of curing a fat-rich fish in oil as in the process of preparing a sardine, and much the same thing occurs in the curing in brine of herrings. It is to be noted that the curing of fat-poor fish, such as cod and ling, by salting and drying differs materially from the process above indicated.

The most successful (both commercially and economically) exploitation of such a fishery as the summer-herring one in the Manx waters is undoubtedly the curing, in various ways, of the great bulk of the fish caught. The processes of distribution can thus best be controlled, the product becomes a better one from the food point of view, and local industries are established. A clamant need of the present time, and indeed of normal times, is the curing of summer-caught herrings for consumption in the winter months, when fat-rich foods are more useful than in the warmer months.

It will be seen from Mr. Scott's report, that young herrings and sprats, caught in the winter, have a much smaller proportion of fat than these summer-caught herrings. Many of these fish are cured in the sardine form, but it is to be noted that the lean winter-caught sprat is not so suitable for this purpose as the fat summer herring. A very great advance in the progress of the local fisheries would be made if it could be discovered where these sprats, that are so abundant off our shores in the winter months, are during the summer, and if they could be profitably fished.

The Manx Herring Fisheries of 1914 and 1916.

The differences in the fisheries of one year and another are illustrated by the analyses of herrings made in 1914 and 1916. In 1914 the Manx herrings attained their maximum of fat at the beginning of July (about 33 per cent.). In 1916 the corresponding maximum was observed at about the beginning of September (about 33 per cent.), that is, two months later. Doubtless the cause was a physical one, but there are no indications as to what it may have been.

The Welsh Herring Fisheries.

The Welsh herring fishery contrasts sharply with the Manx one So far neither has been studied as thoroughly as it ought to have been, but some comparisons are interesting. Being a winter fishery the Welsh one is less valuable, for the fish are poor in fat and are therefore less nutritious. It is a smaller fishery than that off the Isle of Man. The herrings most probably belong to a different "race," or elementary species, as the biometric investigations indicate, but owing to the great difficulty of procuring samples the Welsh herrings have not been nearly so thoroughly studied as the Manx ones.

The Welsh herring shoals spawn locally, some time in November or December, but the time varies on the coast between New Quay Head and the North of Anglesey. At the beginning of the season (in October) the Welsh herrings are immature (Stage I.), but towards the end of the season (in December and January) they are mature, spawning, or spent (Stages VII. and I.) It is to be noted that there is quite a marked difference in sea temperature between the southern extremity of Cardigan Bay, and Beaumaris and Red Wharf Bays, and this physical difference is doubtless related to the difference in spawning time in different localities.

Further, the composition of the shoals reaching shallow water off the Welsh Coasts appears to vary with the locality. The fish do not show the same range of length, and this indicates that the shoals are of different ages. But far too little investigation has been made to show up this difference very clearly.

Life-History of the Plaice in Lancashire and Welsh Waters.

A considerable volume of data has now been accumulated with regard to this subject, and advantage has been taken of the necessary cessation of the investigations to summarise these results. They are now in manuscript form and will be published when it is appropriate.

Size of Plaice in Local Waters.

About 134,000 fish have been individually measured on board the Committee's vessels immediately after capture. The localities of capture and all other associated information are known.

Tables have been prepared showing the range of sizes of the plaice captured and measured on each important fishing-ground, and at each month during the various periods of the fisheries.

These data have been reduced statistically, so that the degree of probability of the conclusions derivable from them can be reckoned. This has involved a considerable degree of arithmetical work, but such is necessary if the results are to be employed in framing regulations. Crude data of observation, by themselves, are of little statistical value.

Theoretical frequency curves, and "tables of dispersion" based on the above measurements have been prepared.

Large-scale graphs, or curves, have been drawn to represent the corrected and uncorrected data.

An account of the statistical methods, which it is hoped present some novel features with regard to treatment, has been prepared.

Age and Sexual Maturity of Plaice in Local Waters.

About 8,000 plaice sent to the Liverpool and Piel Laboratories have each of them been measured, weighed, and dissected so as to find the age and degree of sexual maturity. Tables are given showing the growth-rate of male and female plaice, and curves and measures of dispersion have been made from the tables.

Practically all plaice in the sea off the coasts of Lancashire and Cheshire and North Wales are immature fish. Spawning plaice do not occur. Large plaice come inshore for a short time during the autumn. Large plaice also come into Red Wharf Bay and thereabout during the winter, also for a short time.

Good series of data for the very immature plaice of the Mersey shrimping grounds have been obtained.

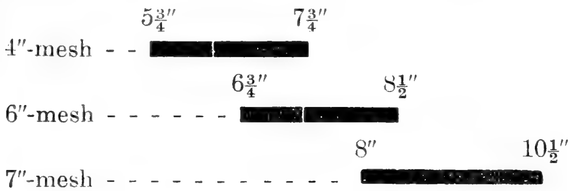
The Effect of different Trawl-meshes.

Tables showing the sizes of plaice caught by trawl-nets of 2″, 4″, 6″, and 7″ mesh have been compiled.

The tables, just as they are, give little information, though they give, of course, the actual observations made. Thus :—

	Largest fish caught.	Average size.	Smallest fish caught.
4″	$14\frac{3}{4}$″	$7\frac{1}{4}$″	$4\frac{1}{2}$″
6″	13″	8″	5″
7″	13″	$8\frac{3}{4}$″	$5\frac{3}{4}$″

But there were far more fish caught of sizes near the averages, and we have to consider how they are clustered together, that is, we have to find the "dispersions" before the information is of much use.



These dispersions are shown above. Half of all the fish caught by the 7″ mesh, for instance, were 8″ to $10\frac{1}{2}''$ in length, and half of all the fish taken by the 6″ mesh were $6\frac{3}{4}''$ to $8\frac{1}{2}''$ in length. If we had considered a dispersion of one-third we should have found that the two catches (6″ and 7″) did not overlap. Then we could have said that the chance that all the plaice caught by a 7″ mesh were bigger than all the fish caught by a 6″ mesh was about 1 in 3.

The Migrations of Plaice.

All the data obtained in the past have been considered. Of the experiments made, those made near the Nelson Buoy summer plaice fishing-grounds give the most interesting results.

These results are charted as a series of nine charts showing the migrations from month to month throughout the year.

Attempts have been made to show how these migrations depend on the sea-temperature and its variation from month to month. But the hydrographic data are not full enough to make this connection more than probable.

AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.—PART X.

By W. A. Herdman, F.R.S., Andrew Scott, A.L.S., and H. Mabel Lewis, B.A.

[ABSTRACT ONLY.]

We have now completed ten years of this intensive study of the plankton of a small area near the centre of the Irish Sea. Had times been normal we should now have drawn up and submitted to the Committee a comprehensive report upon the ten years' work, with a discussion of such conclusions as we have arrived at. Under present conditions, however, this is impossible; so we retain our sheets of data, tables, curves and other results in the hope that we may be enabled to discuss and publish them on some future occasion, and must be content now to record a mere outline of the past year's work on similar lines to the statement given in our last report.

During 1916 we have been enabled to collect 496 samples, which, added to the 4,620 of the previous nine years, gives us 5,116 in all—well over the 5,000 samples which we had desired to work with. Of the nearly 500 samples of the past year 286 were taken regularly week by week throughout the year by the staff of the Port Erin Biological Station, and 210 were special gatherings taken by Professor Herdman from a motor boat during April, August, and September. Well over 20 (24 or 27) official gatherings were taken in each month, except January (15) and October (14) when the weather was exceptionally bad at sea.

The spring maximum for the total plankton in 1916 was in June, a month later than in 1915 and several previous years, and the monthly average haul was 61·8 c.c.—the largest actual haul (= coarse and fine nets combined) being 175 c.c. on June 16th. The amount of the catches during that month was, however, much increased by the quantity of Halosphaera present. In 1915 when the highest monthly average was 63·5 c.c., in May, the bulk of the largest catches was also due to Halosphaera.

The Diatom maximum in 1916 was in May when the monthly average in estimated number of individuals per haul was over seven millions, the actual greatest haul being 24,260,800 Diatoms (mainly *Chaetoceras*) on May 25th.

The autumnal maximum was again very slightly marked, although rather larger than in the previous year. The monthly average reached 11·3 c.c. in September, as against an autumnal maximum of 8·9 c.c. for October, 1915.

Again there were no vast swarms of Diatoms this year in the district. There were particularly few members of the genera *Rhizosolenia, Guinardia* and *Lauderia.* By far the most abundant forms were species of *Chaetoceras*—amounting to about 25 times as many as those of any other genus of Diatoms.

The maxima of the leading groups succeeded one another in the usual order, as follows :—

In May, the Diatom maximum.
[In June, the Total plankton maximum.]
In July, the Dinoflagellate maximum.
In September, the Copepod maximum.

The monthly average number of Dinoflagellates for July was 148,241, the actual largest number being 316,400 on July 6th, and of these 300,000 were *Ceratium tripos* which as usual was much more abundant than the species of *Peridinium.* These Dinoflagellate numbers are rather higher than those for 1915.

Copepoda were abundant in July, August, and September, as the following numbers of individuals show :—

July, monthly average =	45,307,	largest haul =	94,648	on July 27th.
August, ,, ,,	39,739,	,, ,,	95,526	on Aug. 28th.
Sept., ,, ,,	57,616,	,, ,,	118,524	on Sept. 25th.

This last number agrees very closely with the largest haul in 1915 (117,340 individuals on August 2nd). A swarm of *Calanus* appeared in the bay on July 11th, when over 12,000 specimens were taken in a haul. A few days before a similar haul gave only 10 specimens, and a few days after 200.

The largest single hauls of fish-eggs in 1916 were on March 31st (284), April 1st (450 and 396), April 3rd (334 and 287), April 10th (295 and 278), April 15th (249, 256 and 259), April 19th (344), and May 4th (352).

The remaining groups of small animals (chiefly Medusae, Cladocera, Sagitta and Oikopleura) and the various larval forms (Echinoderm, Molluscan, &c.) which make up the rest of our plankton gatherings have been identified and computed as usual, and we have detailed records of their distribution throughout the year. As in 1915, they present no unusual features that call for special remark, but simply confirm more or less exactly statements which we have given in previous reports, and which we hope to formulate more definitely and discuss in detail when it becomes possible to publish the full results of this ten years' survey of Irish Sea plankton.

THE EXPLOITATION OF INSHORE FISHERIES.

By Professor W. A. Herdman, F.R.S.

Many "Advisory" and other Committees, some in connection with the great Government Departments, and others among the leading Scientific Societies, are at present engaged in deliberations and investigations in connection with the great war we are waging, not merely with immediate and pressing war problems but also with the later and possibly equally important after-war questions, which are bound to arise affecting the prosperity of the country and the maintenance of the Empire. A large number of these matters turn upon the application of scientific knowledge and scientific methods to various industries, and amongst these not the least important are those concerned with the allied subjects of agriculture and aquiculture or the scientific regulation and cultivation of our land crops and our sea fisheries.

It is now generally recognised that, both for the present maintenance of the country and also with the view of making a rapid recovery from the effects of the war, amongst other things agriculture and allied industries must be vigorously promoted, and it must be seen to that no suitable land is wasted, that none is applied to the wrong purpose, and that the most favourable treatment to ensure the best results is given to each area. In fact, a more systematic study and more intensive cultivation of the land must be made. In quite a similar way, and for no less important reasons, the harvest of the sea must be promoted, the fisheries must be continuously investigated, and such cultivation as is possible must be applied to our barren shores—and all such fisheries investigation and cultivation is one of the natural applications of Biological Science, and ought to be supported by Sea-Fisheries Administrators and carried out under the direction of specially trained marine biologists.

Now that considerable areas of the usual British fishing grounds are either closed to trawlers or impracticable for the usual fishing operations, any increase of employment on the sea-shore and in shallow waters round the coast may be of direct and immediate advantage both to the men and to the country. Such industries as shell-fish cultivation, shrimping and prawning, whitebait and sprat fishing, and herring fishing and curing, if extended and exploited judiciously, will add to employment, will increase the food supply of the country, and may lead to the establishment of permanent industries of a profitable nature. On the West coast the Lancashire and Western Sea-Fisheries Committee have been alive to such possibilities for some time past, and much of their scientific fisheries work has been directed towards showing the improvements that might be introduced in connection with the local shell-fish industries. It has been shown in their Annual Reports how mussels and cockles can be fattened and greatly increased in value by transplanting to better feeding grounds, and how, if reared in sewage polluted waters, they can then be cleansed and purified before being sent to market. Our Local Fisheries Committee, realising the present opportunity of helping such deserving industries, have worked out several concrete cases where a moderate expenditure, either in transplanting or in purifying the shell-fish or both, would be likely to give immediate beneficial results; and so far as opportunity offers they are endeavouring to promote such useful work. This is not a time when it is easy to induce public bodies to undertake any fresh expense, but it will be unfortunate for the country if such directly productive expenditure, which may reasonably be expected to lead to the establishment of permanent shell-fish industries, be prevented or delayed for want of the comparatively small sums which are necessary to start the work.

As an example of what can be done at a small cost to improve the value of shell-fish by judicious transplanting, the work carried out by the Committee in 1903-5 may be recalled. A full account of these operations was given by Mr. Andrew Scott and Mr. Thomas Baxter in the Lancashire Sea-Fisheries Laboratory Report for 1905. The work was carried out on the mussel beds at Heysham in Morecambe Bay, probably the most extensive mussel-producing grounds on the West coast of England.

In 1903 the Committee gave a grant of £50 to be expended on labour in transplanting over-crowded and stunted mussels, which were not showing any growth, to neighbouring areas which were not so thickly populated. The result was most striking. At the end of a few months the old starved under-sized "blue-nebs," as they are called, had grown $\frac{3}{8}$ of an inch or more, and had reached legal selling size. The animals inside the shell were in fine condition, and these mussels found a ready market at a good price. Mussels, which in their original condition could never have been of any use as food, had been turned into a valuable commodity at comparatively little trouble and expense. The money value to the fishermen of these mussels that had been transplanted for £50 was estimated to have been at least £500.

In 1904, again, a grant of £50 resulted in the transplanting of undersized mussels which were later on sold at a profit of over £500.

In the following year (1905) a grant of £75 resulted in the sale of the transplanted mussels some months later for £579. On that occasion over 240 tons of the under-sized mussels had been transplanted in six days' work. It was found that on the average the transplanting increased the bulk of the mussels about $2\frac{1}{2}$ times, and the increase in length to the original shell was in some cases well over an inch.

Experiments have also been made on the Lancashire coast in the transplantation of cockles from over-crowded to less crowded sands with equally favourable results.*

It is obvious that when, on the conclusion of war, many men return to work along our coasts, any increase of employment in connection with local fishing industries will be of direct and immediate advantage to the country. It is to be hoped that nothing will be allowed to interfere with this work, and that whenever possible further funds will be devoted towards the promotion of schemes which seem desirable, if not indeed essential, from the point of view of the industry and of public health alike. In connection with the public health aspect of the matter, much of Dr. Johnstone's work on the Lancashire coast for some years back has dealt with the condition of the shell-fish beds in relation to sewage contamination, by means both of topographical inspection on the shore and of subsequent bacteriological investigations of samples in the laboratory. All this work has been recorded in detail in our recent Annual Reports, so it is unnecessary for me to say anything further than to emphatically declare my belief in the very great importance of this work.

As an example of a local fishery which has been started as the result of a little ingenuity and enterprise, we may take the Morecambe winter sprat fishery which has developed during the last few years. The fish are being caught in great quantities by a new method, which is the "stow" net modified to suit the conditions prevailing in the strong tidal currents of the Morecambe Bay channels. As many as twenty-five boats were employed in one day during last winter's fishery, which began in October, 1915, and lasted till March, 1916. The invasion

* For further details, reference must be made to the successive Annual Reports of the Committee.

of sprats apparently sets in from the South, sometimes as early as September. The fish become very abundant off Morecambe towards the end of November, and remain in quantity until the end of January, after which the sprats become smaller and the fishery diminishes in value. During the height of the fishery fully 70 tons of fish were landed per day, and the money value of this catch to the fishermen was over £300. A ton of sprats contains on an average 130,000 fish. In a day's fishing, therefore, 9 millions of sprats may be captured, and this goes on day after day without making any appreciable difference to the abundance of the fish. A full account of this recent fishery and the method of using the stow-net was given by Mr. Andrew Scott in our Report for 1915. The question naturally occurs in connection with this and other similar fisheries elsewhere, whether it would not be possible and desirable in the interests of the food supply, to establish a salting and curing industry to convert the temporary superabundance of the fresh perishable fish into a more permanent and highly nutritious article of diet.

Another interesting and very profitable local fishery, which has arisen or been resuscitated quite recently in the Irish Sea, is the summer herring fishery off the south end of the Isle of Man. In former days, say about forty years ago, there seems to have been a regular summer herring fishery prosecuted chiefly by the fleets from Peel and Port St. Mary, but for the last thirty years or so (since about 1883) the fishery has failed—according to some because of the absence of the shoals of herring, and according to others because the men had found more profitable employment on shore in connection with summer visitors to the Island. Probably also the withdrawal of facilities for getting the catch to market rapidly by means of Liverpool tug-boats had an effect. It may be doubted whether there was ever any great change in the distribution and abundance of the herrings, and it has often been said at Fisheries Conferences that, if the boats were manned, equipped and sent to sea, the herring would be found to be as abundant now as they had been in the past. A few years ago a philanthropic body in the Isle of Man (the "Noble" Trustees) with some funds at their disposal induced a firm of herring buyers and curers from Scotland to establish a branch of their business temporarily at Port St. Mary, where they were given special facilities by the Harbour Board for the erection of their sheds and stores; and the presence of this curing establishment, guaranteeing to buy at a reasonable price all the fish that were brought in by the boats, so stimulated the local fishermen that a fleet of about forty boats was equipped and went to sea, and as a result a profitable fishery ensued. The fishermen were satisfied that the old times had come back, and that the herring shoals were once more visiting the seas around their Island. That was in the summer of 1910, and the same conditions held good for the two following years. Only the one buyer was in the market and the prices he gave ranged from 14s. to 18s. the cran during the three years 1910-1912. In the following summer four rival fish-curers had establishments at Port St. Mary and Peel and, as the result of competition, the prices paid for the herring to the fishermen rose from a maximum of 18s. the cran in 1912 to a maximum of 40s. the cran in 1913.

In 1914 only two curers opened establishments at Port St. Mary, and as a result, it is said, of a private arrangement between them in the earlier part of the season prices fell as low as 7s. a cran. Later on, however, the arrangement broke down, healthy competition took place, and prices rose to the respectable maximum of 30s. the cran.

Last year (1915) was the most profitable season. The fishery lasted for nearly three months (July 8th to September 28th), over forty boats were engaged in it at Port St. Mary alone, four rival buyers and curers were present, and the prices ranged from 21s. at the beginning when the fish were small and of poorer quality to the remarkable maximum of 91s. the cran—and this price was not an isolated case, but was reached on several different occasions, as I have seen in the auctioneer's record of the daily sales. On September 15th eight boats earned between them over £500.

In the present summer (1916) the fishery was, at first, less prosperous. Only one curing establishment opened at Port St. Mary in the earlier part of the season, although others were expected later. As a result fewer boats (about fifteen) were fishing, and the single buyer paid a fixed price of 23s. the cran for all fish brought into Port St. Mary. As the season went on prices improved, and by August 30th a second buyer had appeared and the prices had risen to 45s. the cran. By the middle of September there was a marked improvement both in the quality of the fish and the state of the market. Four additional buyers and curers were at work, and towards the end of the month one boat sold its catch of 100 crans at the record price of 97s. a cran.

This early summer, however, the fishery at Peel on the other side of the Island has been much more profitable. About thirty-six sailing boats and half a dozen steam drifters from the East coast have been engaged in it, while the presence of five competing buyers has resulted in higher prices—on the average about 35s. the cran. One of the buyers has started a service of motor boats running the fresh fish across to Whitehaven on the Cumberland coast, while the others have cured the greater part of the catch at Peel and have sent it to Liverpool to be distributed to other markets.

The conclusion one arrives at from this record of recent years, and from what one can ascertain of conditions in the past, is that—in addition to the presence of the fish, which can probably be relied upon in most years—it is necessary for a prosperous herring fishery in the Isle of Man either that a local market should be constituted by competing buyers and curers from Scotland or elsewhere, or that arrangements should be made to transport the daily catch by steam-carriers to a market on the mainland such as Liverpool, Fleetwood or Holyhead. As a result of the want of market facilities it may be noted that during the greater part of this summer herring have been sold retail at Port Erin at 20 for a shilling, while in Liverpool they cost from three half-pence to twopence half-penny each.

The bulk of the fish, however, were not sold fresh, but were cured in brine to be exported as salt herrings; and, from the point of view of food production, this is probably the best way of dealing with these large summer fisheries. Summer-cured salt herrings are a highly nutritious winter food which ought to be more widely known and more generally used throughout the country.

After the War it will for some time probably be just as important as it is now to prevent money from leaving the country, and with a view to this, as well as for other reasons which I have stated—in brief, the production of food and the employment of demobilised men—it is obviously desirable that all home productivity should be organised and stimulated. The exploitation of minor fishing industries along our shores naturally occurs as one step in this direction, and the economic need for developing these deserving industries seems obvious and urgent.