PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XVII.

SESSION 1902-1903.

LIVERPOOL:
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1903.

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PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents:

1886—87 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—88 J. J. DRYSDALE, M.D.
1888—89 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—90 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—91 T. J. MOORE, C.M.Z.S.
1891—92 T. J. MOORE, C.M.Z.S.
1892—93 ALFRED O. WALKER, J.P., F.L.S.
1893—94 JOHN NEWTON, M.R.C.S.
1894—95 Prof. F. GOTCH, M.A., F.R.S.
1895—96 Prof. R. J. HARVEY GIBSON, M.A.
1896—97 HENRY O. FORBES, LL.D., F.Z.S.
1897—98 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—99 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.

SESSION XVII., 1902-1903.

President:

R. CATON, M.D., F.R.C.P.

Vice-Presidents:

HENRY C. BEASLEY.
Prof. W. A. HERDMAN, D.Sc., F.R.S.

Hon. Treasurer:

T. C. RYLEY.

Hon. Librarian:

JAMES JOHNSTONE, B.Sc.

Hon. Secretary:

JOSEPH A. CLUBB, M.Sc. (Vict.).

Council:

Prof. CAMPBELL BROWN, D.Sc.
W. J. HALLS.
W. HANNA, M.A., M.B.
W. S. LAVEROCK, M.A., B.Sc.
Rev. T. S. LEA, M.A.
ALFRED LEICESTER.
JOSEPH LOMAS, F.G.S.
JOHN NEWTON, M.R.C.S.
Prof. PATERSON, M.D., M.R.C.S.
H. C. ROBINSON.
I. C. THOMPSON, F.L.S.
J. WIGLESWORTH, M.D., F.R.C.P.

REPORT of the COUNCIL.

During the Session 1902-1903 there have been seven ordinary meetings and one field meeting of the Society. The latter was held at Martin Mere, near Southport, and was a joint meeting with the Liverpool Geological Society.

The communications made to the Society have been representative of almost all branches of Biology and the exhibition of microscopic preparations and other objects of interest has been well maintained at the meetings.

By invitation of the Council, Dr. Traquair, Keeper of the Natural History Department, Science and Art Museum, Edinburgh, lectured on June 12th on "The Earliest Records of Vertebrate Life." Special invitations were issued, and a large and representative audience assembled.

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

The Treasurer's statement and balance sheet are appended.

No alterations have been made in the Laws of the Society during the past session, but a new Bye-law (see page xix.) has been added, forming an Associate Membership.

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

Honorary Members	8
Ordinary Members	52
Student Members	26
Total	86

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the seventeenth session was held at University College on Friday, October 17th, 1902.

The President-elect (Dr. Caton) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1901-1902 (see "Proceedings," Vol. XVI., p. viii.) was submitted and adopted.

2. The Treasurer's Balance Sheet for the Session 1901-1902 (see "Proceedings," Vol. XVI., p. xxxi.) was submitted and approved.

3. The Librarian's Report (see "Proceedings," Vol. XVI., p. xxiii.) was submitted and approved.

4. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, Henry C. Beasley and Professor Herdman, D.Sc., F.R.S.; Hon. Treasurer, T. C. Ryley; Hon. Librarian, James Johnstone, B.Sc.; Hon. Secretary, Joseph A. Clubb, M.Sc.; Council, Prof. Campbell Brown, D.Sc., W. J. Halls, W. Hanna, M.A., M.B., Rev. T. S. Lea, M.A., W. S. Laverock, M.A., B.Sc., Alfred Leicester, Joseph Lomas, F.G.S., John Newton, M.R.C.S., Prof. Paterson, M.D., M.R.C.S., H. C. Robinson, I. C. Thompson, F.L.S., and J. Wiglesworth, M.D., F.R.C.P.

5. Dr. Caton delivered the Presidential Address, entitled "Acquired Differences in Structure and Function between the Right and Left Sides of the Body" (see "Transactions," p. 1). A vote of thanks was proposed by Prof. Herdman, seconded by Dr. Newton, and carried with acclamation.

The second meeting of the seventeenth session was held at University College, on Friday, November 14th, 1902. The President in the chair.

1. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 15).

2. Prof. Herdman, F.R.S., gave a lecture on his recent expedition to Ceylon, and of the Pearl Oyster Fisheries of the Gulf of Manaar. His remarks were illustrated by a fine series of lantern slides, many of which were prepared from original photographs. The typical scenes, natives, industries, methods of pearl fishing, and many interesting incidents of the expedition were depicted.

The third meeting of the seventeenth session was held at University College, on Friday, December 12th, 1902. The President in the chair.

1. A paper on a marine Chironomid, new to Britain, by Mr. A. D. Imms, was laid on the table (see "Transactions," p. 81).

2. Dr. J. Wiglesworth gave a lecture on "St. Kilda and its Birds," being an account of a recent visit to the island (see "Transactions," p. 319).

The fourth meeting of the seventeenth session was held at University College, on Friday, January 9th, 1903. The President in the chair.

1. Mr. Walter Tattersall, B.Sc., communicated a paper on the "Classification and Distribution of the Cephalochorda" (see "Transactions," p. 269).

2. Mr. H. C. Robinson gave an account of a recent expedition, along with Mr. Annandale, to the Malay Peninsula. His remarks were illustrated by a series of lantern slides, prepared from original photographs.

The fifth meeting of the seventeenth session was held at University College, on Friday, February 20th, 1903. The President in the chair.

1. A paper on "The Habits and Structure of the Onuphid Worms," by Mr. Arnold T. Watson, was communicated (see "Transactions," p. 303).

2. Professor Sherrington, F.R.S., gave a lecture on "The Functions of the Brain, as examined by experiments on the Anthropoid Apes."

The sixth meeting of the seventeenth session was held at University College, on Friday, March 13th, 1903. The President in the chair.

1. Mr. I. C. Thompson communicated a note on two species of Parasitic Copepoda recently taken near Port Erin, new to the local fauna.

2. The Rev. T. S. Lea, M.A., communicated a note on some submerged tree trunks near Holyhead, as follows:—"The Island of Mona, or Holy Island, on which Holyhead is situated, is separated from Anglesey by a shallow channel of variable width and with several bays or inlets. At the two

narrowest places the channel is crossed by causeways, the northern one carrying the main road and the L. and N.W.R., and the other being merely a roadway. In each there is an opening which partially admits the tide to so wide an expanse of lagoon that the water never reaches flood tide level nor falls to low-water mark. One of the bays, or inlets, of this lake stretches westwards towards the sea at Tre-arrdur Bay, from which it is only separated by about a quarter of a mile of salt marsh and a range of sand dunes. At high tide, therefore, there is nothing but the sand dunes, backed by some sandy fields, which may cover rock, to keep the sea from cutting Holy Island in two and entering the inlet of the lake. There is, however, no record that it has ever done this. But in Tre-arrdur Bay are stumps of trees *in situ* on the shore from about half-tide downwards; as far as I could judge, below the level of the lake and its marshes. A legend tells that St. Bridget of old crossed from Ireland on a green sod, which became a hillock, on which she built a chapel. This chapel was, as it seems, in existence a century ago, surrounded by oak trees, said to be the same whose stumps remain. But the sea made an inroad, and destroyed the chapel and the trees. Now the northern causeway is comparatively new, and, consequently, the level of the water in the lagoon must have formerly been the same as that of the sea. Had the sea merely forced back the sand dunes, under present conditions the trees might have been growing below high-water mark, though it is unlikely. But, as they stand, the only conclusion seems to be that either they are not the remains of the trees near the old chapel, but a relic of the general submerged forests of this coast, or else that there has been a remarkable change in level thereabouts in very recent years, of which there is no trace elsewhere. If any of our members care to look into the matter, it is worth an excursion from Holyhead. The shores of the lagoon seem rich in botany, especially the rare *Inula crithmoides*."

3. Prof. Herdman, F.R.S., communicated the Annual Report of the investigations carried on during 1902, in connection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 87).

The seventh meeting of the seventeenth session was held at University College, on Friday, June 12th, 1903. The President in the chair.

1. Dr. Traquair, Keeper of the Natural History Department, Science and Art Museum, Edinburgh, lectured before the Society on "The Earliest Records of Vertebrate Life." The lecture was of great scientific importance, including much of Dr. Traquair's most recent work; and it is hoped that the paper will be published in full in the Transactions of the Society for next Session.

The eighth meeting of the seventeenth session was a Field Meeting, held jointly with the Liverpool Geological Society, at Martin Mere, near Southport, on Saturday, June 20th, 1903. Mr. Harold Brodrick, M.A. (Geological Society), acted as Leader.

1. After tea a short business meeting was held. On the motion of Prof. Herdman, from the chair, seconded by Mr. J. Lomas, the Rev. T. S. Lea, M.A., was unanimously elected President for the ensuing session.

LAWS of the LIVERPOOL BIOLOGICAL SOCIETY.

I.—The name of the Society shall be the "LIVERPOOL BIOLOGICAL SOCIETY," and its object the advancement of Biological Science.

II.—The Ordinary Meetings of the Society shall be held at University College, at Seven o'clock, during the six Winter months, on the second Friday evening in every month, or at such other place or time as the Council may appoint.

III.—The business of the Society shall be conducted by a President, two Vice-Presidents, a Treasurer, a Secretary, a Librarian, and twelve other Members, who shall form a Council; four to constitute a quorum.

IV.—The President, Vice-Presidents, Treasurer, Secretary, Librarian and Council shall be elected annually, by ballot, in the manner hereinafter mentioned.

V.—The President shall be elected by the Council (subject to the approval of the Society) at the last Meeting of the Session, and take office at the ensuing Annual Meeting.

VI.—The mode of election of the Vice-Presidents, Treasurer, Secretary, Librarian, and Council shall be in the form and manner following:—It shall be the duty of the retiring Council at their final meeting to suggest the names of Members to fill the offices of Vice-Presidents, Treasurer, Secretary, Librarian, and of four Members who were not on the last Council to be on the Council for the ensuing session, and formally to submit to the Society, for election at the Annual Meeting, the names so suggested. The Secretary shall make out and send to each Member of the Society, with the circular convening the Annual Meeting, a printed list of the retiring Council, stating the date of the election of each Member, and the number of his attendances at the Council Meetings during the past session; and another containing the names of the Members suggested for election, by which lists, and no others, the votes shall be taken. It shall, however, be open to any Member to substitute any other names in place of those upon the lists, sufficient space being left for that purpose. Should any list when delivered to the President contain other than the proper number of names, that list and the votes thereby given shall be absolutely void. Every list must be handed in personally by the Member at the time of voting. Vacancies occurring otherwise than by regular annual retirement shall be filled by the Council.

VII.—Every Candidate for Membership shall be proposed by three or more Members, one of the proposers from personal knowledge. The nomination shall be read from the Chair at any Ordinary Meeting, and the Candidate therein recommended shall be balloted for at the succeeding Ordinary Meeting. Ten black balls shall exclude.

VIII.—When a person has been elected a Member, the Secretary shall inform him thereof, by letter, and shall at the same time forward him a copy of the Laws of the Society.

IX.—Every person so elected shall within one calendar month after the date of such election pay an Entrance Fee of Half a Guinea and an Annual Subscription of One

Guinea (except in the case of Student Members); but the Council shall have the power, in exceptional cases, of extending the period for such payment. No Entrance Fee shall be paid on re-election by any Member who has paid such fee.

X.—The Subscription (except in the case of Student Members) shall be One Guinea per annum, payable in advance, on the day of the Annual Meeting in October.

XI.—Members may compound for their Annual Subscription by a single payment of Ten Guineas.

XII.—There shall also be a class of Student Members, paying an Entrance Fee of Two Shillings and Sixpence, and a Subscription of Five Shillings per annum.

XIII.—All nominations of Student Members shall be passed by the Council previous to nomination at an Ordinary Meeting. When elected, Student Members shall be entitled to all privileges of Ordinary Members, except that they shall not receive the publications of the Society, nor vote at the Meetings, nor serve on the Council.

XIV.—Resignation of Membership shall be signified *in writing* to the Secretary, but the Member so resigning shall be liable for the payment of his Annual Subscription, and all arrears up to date of his resignation.

XV.—The Annual Meeting shall be held on the second Friday in October, or such other convenient day in the month, as the Council may appoint, when a report of the Council on the affairs of the Society, and a Balance Sheet duly signed by the Auditors previously appointed by the Council, shall be read.

XVI.—Any person (not resident within ten miles of Liverpool) eminent in Biological Science, or who may have rendered valuable services to the Society, shall be eligible as an Honorary Member; but the number of such Members shall not exceed fifteen at any one time.

XVII.—Captains of vessels and others contributing objects of interest shall be admissible as Associates for a period of three years, subject to re-election at the end of that time.

XVIII.—Such Honorary Members and Associates shall be nominated by the Council, elected by a majority at an Ordinary Meeting, and have the privilege of attending and taking part in the Meetings of the Society, but not voting.

XIX.—Should there appear cause in the opinion of the Council for the expulsion from the Society of any Member, a Special General Meeting of the Society shall be called by the Council for that purpose; and if two-thirds of those voting agree that such Member be expelled, the Chairman shall declare this decision, and the name of such Member shall be erased from the books.

XX.—Every Member shall have the privilege of introducing one visitor at each Ordinary Meeting. The same person shall not be admissible more than twice during the same session.

XXI.—Notices of all Ordinary or Special Meetings shall be issued to each Member by the Secretary, at least three days before such Meeting.

XXII.—The President, Council, or any ten Members can convene a Special General Meeting, to be called within fourteen days, by giving notice in writing to the Secretary, and stating the object of the desired Meeting. The circular convening the Meeting must state the purpose thereof.

XXIII.—Votes in all elections shall be taken by ballot, and in other cases by show of hands, unless a ballot be first demanded.

XXIV.—No alteration shall be made in these Laws, except at an Annual Meeting, or a Special Meeting called for that purpose; and notice in writing of any proposed alteration shall be given to the Council, and read at the Ordinary Meeting, at least a month previous to the meeting at which such alteration is to be considered, and the proposed alteration shall also be printed in the circular convening such meeting; but the Council shall have the power of enacting such Bye-Laws, as may be deemed necessary, which Bye-Laws shall have the full power of Laws until the ensuing Annual Meeting, or a Special Meeting convened for their consideration.

BYE-LAWS.

1. Student Members of the Society may be admitted as Ordinary Members without re-election upon payment of the Ordinary Member's Subscription; and they shall be exempt from the Ordinary Member's Entrance Fee.

2. University College Students may be admitted as Student Members of the Society for the period of their college residence, on the single payment of a fee of Five Shillings and an entrance fee of Two Shillings and Sixpence.

3. Persons wishing it, may, subject to the approval of the Council, be admitted as Associates of the Society on payment of an Entrance Fee of Two Shillings and Sixpence, and an Annual Subscription of Ten Shillings and Sixpence, such Associates to have the privileges of Ordinary Members except the right to a copy of the Annual Volume of Transactions.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1902-1903.

A. Ordinary Members.

(Life Members are marked with an asterisk.)

ELECTED.

1899 Annett, Dr. H. J., University College, Liverpool.

1898 Armour, Dr. T. R. W., University College, Liverpool.

1886 Banks, Sir W. Mitchell, M.D., F.R.C.S., 28, Rodney-street.

1888 Beasley, Henry C., Vice-President, Prince Alfred-road, Wavertree.

1894 Boyce, Prof., University College, Liverpool.

1889 Brown, Prof. J. Campbell, 8, Abercromby-square.

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

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

1900 Cole, F. J., University College, Liverpool.

1902 Cowley, R. C., 6, Sandon-terrace, Liverpool.

1897 Dutton, Dr. J. Everett, 44, Upper Parliament-street, Liverpool.

1900 Ellis, Dr. J. W., 18, Rodney-street, Liverpool.

1886 Gibson, Prof. R. J. Harvey, M.A., F.L.S., University College.

1902 Glynn, Dr. Ernest, 67, Rodney-street.

1886 Halls, W. J., 35, Lord-street.

1901 Hanna, W., M.A., M.B., 25, Park-way, Liverpool.

1896 Haydon, W. T., 135, Bedford-street S.

1900 Haywood, Lt.-Col. A. G., Rearsby, Blundellsands.
1886 Herdman, Prof. W. A., D.Sc., F.R.S., VICE-PRESIDENT, University College.
1893 Herdman, Mrs., B.Sc., Croxteth Lodge, Ullet-road, Liverpool.
1897 Holt, Alfred, Crofton, Aigburth.
1902 Holt, A., jun., Crofton, Aigburth.
1900 Horsley, Dr. Reg., Stonyhurst, Blackburn.
1898 Johnstone, James, B.Sc., HON. LIBRARIAN, University College, Liverpool.
1886 Jones, Charles W., Allerton Beeches.
1902 Jones, E. Dukinfield, 11, Bertram-road.
1901 Layton, P., Glendale, Leyfield-road, West Derby.
1894 Lea, Rev. T. S., M.A., St. Ambrose Vicarage, Widnes.
1886 Leicester, Alfred, Scot Dale, New Ferry.
1896 Laverock, W. S., M.A., B.Sc., Free Museums, Liverpool.
1886 Lomas, J., Assoc. N.S.S., F.G.S., 13, Moss-grove, Birkenhead.
1888 Newton, John, M.R.C.S., 2, Prince's Gate, W.
1900 Nisbet, Dr., 7, Croxteth-road, Liverpool.
1894 Paterson, Prof., M.D., M.R.C.S., University College, Liverpool.
1894 Paul, Prof. F. T., Rodney-street, Liverpool.
1897 Quayle, Alfred, 7, Scarisbrick New-road, Southport.
1890 *Rathbone, Miss May, Backwood, Neston.
1897 Robinson, H. C., Holmfield, Aigburth.
1900 Rylands, Ralph, 2, Charlesville, Claughton.
1887 Ryley, Thomas C., HON. TREASURER, 10, Waverley-road.
1894 Scott, Andrew, Piel, Barrow-in-Furness.
1895 Sherrington, Prof., M.D., F.R.S., University College, Liverpool.

1900 Smith, Mrs., 14, Bertram-road, Liverpool.

1886 Smith, Andrew T., 5, Hargreaves-road, Sefton Park.

1895 Smith, J., F.L.S., The Limes, Latchford, Warrington.

1886 Thompson, Isaac C., F.L.S., 53, Croxteth-road.

1889 Thornely, Miss L. R., 17, Aigburth Hall-road.

1888 Toll, J. M., 49, Newsham-drive, Liverpool.

1902 Turner, J. E., 17, Tancred-road, Liverpool.

1891 Wiglesworth, J., M.D., F.R.C.P., County Asylum, Rainhill.

1896 Willmer, Miss J. H., 20, Lorne-road, Oxton, Birkenhead.

B. Student Members.

Bramley-Moore, J., 138, Chatham-street.

Carstairs, Miss, 39, Lily-road, Fairfield

Drinkwater, E. H., Rydal Mount, Marlboro'-road, Tuebrook.

Elder, D., 49, Richmond Park, Liverpool.

Graham, Miss Mary, Ballure House, Gt. Crosby.

Hannah, J. H. W., 55, Avondale-road, Sefton Park.

Harrison, Oulton, Denehurst, Victoria Park, Wavertree.

Hick, P., 3, Victoria Drive, Rock Ferry.

Hudson, Miss K. B., University Hall, Edge-lane.

Hunter, S. F., Westminster Park, Chester.

Jefferies, F., 45, Trafalgar-road, Egremont.

Jones, H., University College, Liverpool.

Knott, Henry, 11, Brereton Avenue, Liverpool.

Law, Arthur, B.Sc., University College, Liverpool.

Lawrie, R. D., Sunnyside, Woodchurch Lane, Birkenhead.

Lloyd, J. T., 43, Ullet-road, Sefton Park.

Mann, J. C., University College, Liverpool.

Mawby, W., 7, Cross-street, Birkenhead.
Pearson, J., 43, Dryden-road.
Stallybrass, C. O., Grove-road, Wallasey.
Scott, G. C., 65, Croxteth-road.
Scott, Miss D., University Hall, Edge-lane.
Smith, G., University College, Liverpool.
Smith, C. H., University College, Liverpool.
Tattersall, W., 290, Stanley-road, Bootle.
Woolfenden, H. F., 6, Grosvenor-road, Birkdale.

C. Honorary Members.

S.A.S. Albert I., Prince de Monaco, 25, Faubourg St. Honore, Paris.
Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.
Claus, Prof. Carl, University, Vienna.
Fritsch, Prof. Anton, Museum, Prague, Bohemia.
Giard, Prof. Alfred, Sorbonne, Paris.
Haeckel, Prof. Dr. E., University, Jena.
Hanitsch, R., Ph.D., Raffles Museum, Singapore.
Solms-Laubach, Prof-Dr., Botan. Instit., Strassburg.

REPORT of the LIBRARIAN.

Lists of the publications added to the Library during the Session 1902-3, and of the Societies, Institutions, &c., to which copies of the "Transactions" are sent, are given below:—

I.—Publications added to the Library during the Session 1902-3.

Amsterdam—Naturk. Tijdschrift V. Nederl.—Indie. Deel 61; 1902.

Amsterdam—K. Akad. Wetenschappen:—Proc. Section of Sciences, Vol. 4, 1902; Verslag Gew. Vergaderingung, Deel 10, 1902; Jaarboek, 1901, Verhand. K. Akad. Wetensch. Deel 8, Deel 9, Nos. 1-2, 1901-2.

Adelaide—Trans. Roy. Soc. S. Australia. Vol. 26, pt. 1. 1902.

Adelaide—Mem. Roy. Soc. S. Australia. Vol. 2, pt. 1. 1902.

Basel—Verhandl. Naturf. Ges. Bd. 13-15, Bd. 16, H. 1. Anhang Bd. 13.

Basel—Verhandl. Naturf. Ges. Namenverzeichnis v. Sachregister der Bd. 6-12.

Berlin—Sitzungsb. Akad. Wissensch. 1902. Nos. 1-53.

Berlin—Mitth. Deutschen See-Fisch. Vereins. Bd. 18. Nos. 2-12. 1902.

Zeitschr. f. Fischerei. Bd. 10, H. 1-4; Bd. 11, H. 1. 1902-3.

Berlin and Upsala—Den Skandinaviska vegatationens spridnings—biologi; Dr. R. Sernander. 1901.

Bergen—Bergens Museums Aarbog. For 1902 and 1903.

Bergen—Crustacea of Norway, G. O. Sars. Vol. 4, pts. 5-15. 1902-3.

Norske Fiskeritidende; Jany., 1903.

Lidt om Raeker og Raekefische. A. Wolleboeck. 1901.

Bergens Mus. Aarsberetning. 1901-1902.

Berlin—Notes de Geographie Biologique Marine par Prince Albert de Monaco. 1900.

Berlin—Sur le Museum Oceanographique de Monaco par Dr. J. Richard. 1900.

Beauvais—Sur l'emploi Desinences Caracteristiques dans denominations des groupes etablis pour les zoologique classifications. C. Janet. 1898.

Birmingham—Records of Meteorological Observations taken at the Observatory, Edgbaston. 1902.

Birmingham—Proc. Nat. Hist. Soc. Vol. 11, pt. 2. 1902.

Bonn—Sitz. Niederrh. Ges. 1901-2.

Bonn—Verhandl. Naturh. Vereins. Jahrg. 58-9. 1901-2.

Boston (U.S.A.)—Proc. Soc. Nat. Hist. Vol. 29, Nos. 15-18; Vol. 30, Nos. 1-2. 1901.

Bordeaux—Proc.—Verb. Soc. Linn. 1901.

Bruxelles—Bull. Classes des Sciences, Acad. Roy. de Belgique. 1902. Nos. 1-12, 1902. Nos. 1-4, 1903.

Annuaire l'Acad. Royale Belgique. 1902-3.

Buenos Aires—Anales Mus. Nac.; T. 7 and 8, 1902.

Bucuresci—Bull. de l'herbier de l'Institut Botanique de Bucarest; No. 2. 1902.

Cambridge (U.S.A.)—Bull. Mus. Comp. Zool. Harvard.

Vol. 38. Nos. 5-6. 1902.

Vol. 39. Nos. 2-5. 1902.

Vol. 40. Nos. 1-5. 1902-3.

Vol. 41. No. 1.

Vol. 49. No. 6.

Vol. 5. Geological Series. Nos. 7-8. 1903.

Annual Report, 1901-2.

Chatham (U.S.A.)—Proc. Miramichi Nat. Hist. Ass.; No. 3. 1903.

Chicago—Field Columbian Museum.

Anthropological Series. Vol. 3, Nos. 2-3. 1901-2.

Zoological Series. Vol. 3, Nos. 6-7.

Botanical Series. Vol. 1, No. 7. 1902.

Geological Series. Vol. 1, Nos. 9-10. 1901.

Botanical Gazette. Vol. 34, Nos. 3-6; Vol. 35, Nos. 1-2.

An. Rep. Directors Field Columbian Museum. 1900-1.

Chicago—Bull. Lloyd Library, Mycological Series. Nos. 1-2. 1902. Mycological Notes. Nos. 5-9. 1902. Pharmacy Series. Nos. 1-2. Reproduction Series. No. 1. 1902.

Chicago—7th An. Report John Crerar Library. 1901.

Christiania—Forhandl. Vidensk.-Selsk. 1901.

Dublin—Sci. Trans. Roy. Dublin Soc. Vol. 7, Nos. 14-16; Vol. 8, No. 1. 1902.

Dublin—Sci. Proc. Roy. Dublin Soc. Vol. 9, Pt. 5. 1903.

Dublin—Economic Proc. Roy. Dublin Soc. Vol. 1, Pt. 3. 1902.

Edinburgh—Proc. Roy. Phys. Soc. Session 1900-1; 1902.

Frankfurt A. M.—Bericht Senckenb. Naturf-Ges. 1902.

Freiburg—Ber. Naturf. Ges. Bd. 12. 1902.

Geneva—Mem. Soc. de Phys. et d'Hist. Nat. Vol. 34. Fasc. 1-3. 1902.

Giessen—Ber. Oberheiss. Ges. 33. 1899-1902.

Gottingen—Nachr. K. Ges. Wissensch.
Math.-Phys. Klasse. H. 3, 1901; H. 1-6, 1902; H. 1-2, 1903.
Gesch. Mitth. H. 1-2. 1902.
Glasgow—Trans. Nat. Hist. Soc. Vol. VI. (N.S.), Pt. 2; 1902.
Fishery Bd. for Scotland:—
Annual Report. Pt. 1 (General Report), 15th to 20th Reports; 1897-1902.
Annual Report. Pt. 2 (Salmon Fisheries), 15th to 20th Reports; 1897-1902.
Annual Report. Pt. 3 (Scientific Investigation), 20th Report; 1902.
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II.—List of Societies, and Institutions and Journals with which Publications are Exchanged.

(Additions made during the current session marked with an asterisk.)

Amsterdam—Koninklijke Akadamie van Wetenschappen.

Koninklijke Zoölogisch Genootschap Natura Artis Magistra.

Baltimore—Johns Hopkins University.

Basel—Naturforschende Gesellschaft.

Batavia—Koninklijke Natuurkundig Vereeniging in Ned. Indie.

Bergen—Museum.

Berlin—Konigl, Akadémie der Wissenschaften.

Deutsche Fisherei-Vereins.

Birmingham—Philosophical Society.

Bolonga—Accademia della Scienze.

Bonn—Naturhistorischer Verein des Preussichen Rheinlande und Westfalens.

Bordeaux—Société Linnéenne.

Boston—Society of Natural History.

Brussels—Académie Royal des Sciences, etc., de Belgique.

Buenos Aires—Museo Nacional.

Museo de la Plata.

Caen—Société Linnéenne de Normandie.

Cambridge—Morphological Laboratories.

Cambridge, Mass.—Museum of Comparative Zoology at Harvard College.

Chicago, U.S.A.—The Field Columbian Museum.

The Botanical Gazette, Chicago University.

The Johns Hopkins University.

Christiania —Videnskabs-Selskabet.
Dublin—Royal Dublin Society.
Edinburgh—Royal Society.
Royal Physical Society.
Royal College of Physicians.
Fishery Board for Scotland.
Frankfurt—Senckenbergische Naturforschende Gesellschaft.
Freiburg—Naturforschende Gesellschaft.
Geneve—Société de Physique et d'Histoire Naturelle.
Giessen—Oberhessische Gesellschaft für Natur und Heilkunde.
Glasgow—Natural History Society.
Gottingen—Konigl. Gesellschaft der Wissenschaften.
Halifax—Nova Scotian Institute of Natural Science.
Halle, A.S.—K. Leopoldinisch-Carolischen Akademie der Naturforscher.
Haarlem—Musée Teyler.
Sociéte Hollandaise des Sciences.
Heligoland—Königliche Biologische Anstalt.
Illinois, U.S.A.—Reports of the State Laboratory of Natural History.
Kiel—Naturwissenschaftliche Verein fur Schleswig—Holstein.
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Leeds—Yorkshire Naturalists' Union.
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Lille—Revue Biologique du Nord de la France.
Liverpool—Geological Society.
Bulletin of the Liverpool Museums.
London—Royal Microscopical Society.
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Marseilles—Station Zoologique d' Endoume.
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Medford (Mass.)—Tufts College Library.
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Melbourne—Royal Society of Victoria.
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MOSCOU—Société Impériale des Naturalistes.
MÜNCHEN—Allgemeine Fischerei-Zeitung.
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MILLPORT—Biological Station.
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Bulletin Scientifique de la France et de la Belgique.
Société de Biologie.
PHILADELPHIA—Academy of Natural Sciences.
PLYMOUTH—Marine Biological Association.
ROMA—Societas Zoologica Italiana.
RENNES—Bulletin Société Scientifique et Medicale.
SALEM, U.S.A.—The Essex Institute.
ST. LOUIS, MISS.—Academy of Sciences.
ST. PETERSBURG—Académie Impériale des Sciences.
SAN FRANCISCO—California Academy of Science.
SANTIAGO—Société Scientifique du Chili.
STAVANGER—Staváanger Museum.
STOCKHOLM—Académie Royale des Sciences.
SYDNEY—Australian Museum.
TOKIO—Imperial University.
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TORINO—Musei de Zoologia ed Anatomia Comparata della R. Universita.
TORONTO—Canadian Institute.
TRIESTE—Societa Adriatica de Scienze Naturali.
UPSALA—Upsala Universitiet.
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URBANA, U.S.A.—Bulletin of the Illinois State Laboratory of Natural History.
WASHINGTON—Smithsonian Institution.
United States National Museum.
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WELLINGTON, N. Z.—New Zealand Institute.
WIEN—K. K. Naturhistorische Hofmuseums.
K. K. Zoologisch—Botanischen Gesellschaft.
ZAGREB—Societas Historica—Naturalis Croatica.
ZURICH—Zurcher Naturforschende Gesellschaft.

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TRANSACTIONS

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ABSTRACT OF INAUGURAL ADDRESS

ON

ACQUIRED DIFFERENCES IN STRUCTURE AND FUNCTION BETWEEN THE RIGHT AND LEFT SIDES OF THE BODY.*

By RICHARD CATON, M.D., F.R.C.P., President.

[17th October, 1902.]

I wish to express to the Society my sincere thanks for the honour they have conferred upon me in electing me President, a post for which I feel myself but very imperfectly qualified. Possessing only a meagre acquaintance with purely Zoological subjects, I propose to select a topic bearing on human and comparative physiology, one which while possessing considerable interest, has not yet been fully dealt with by any writer, namely:—Acquired differences in Structure and Function between the right and left sides of the body, in animals having originally bi-lateral symmetry. I propose to mention a few examples of acquired asymmetry, to consider the antiquity of these examples, to discuss their causes, and the question whether the asymmetry is beneficial or otherwise.

Abundant examples of acquired asymmetry occur among the Mollusca. Typically the Molluscs had symmetrical

* The Paper was illustrated by 30 Lantern Slides.

hemisomes, but among those species which occupy helicoid univalve shells, marked asymmetry has developed. The majority of the Lamellibranchs and the Gastropods possess shells which have acted as a shield or protection to the soft tissues, but which re-acting upon them have produced diversity between the two hemisomes. The modification appears to be very ancient. Among the highest class of Molluscs, the Cephalopoda, remarkable asymmetry appears in the male, in hectocotylisation, a modification of one of the arms to contain the generative products. The antiquity of hectocotylisation in geological time appears to be very great. Passing on to Crustaceans we find in Pagurids, the hermit crabs, a moulding of the body into non-symmetrical form to fit the helicoid shell of a Mollusc, a consequent shrinking of the chela adjacent to the shell and an increased growth of that more remote from it. The case is very similar to that of the mollusc.

Among the Crustaceans there are also certain crabs, such as *Gelasimus pugilator*, in which, in the male, one claw is a great deal larger than the other; according to Yarkes, of Harvard, the right claw is the larger in 52 per cent. of examples, while in 48 per cent. the augmentation is in the left; he finds that the right clawed or right handed crabs are larger than the left handed ones, and less variable also. The same phenomenon is seen in *Gelasimus maracoani* and in *G. vocans*, the calling crab (so named from its habit of beckoning with the big claw), in *Cardisoma* and many others; among the prawns also as in *Axius stirhynchus* and *Callianassa subterranea*. The possession of one large and powerful claw may make the male animal more formidable than would the possession of two of more moderate size. As to the antiquity of this acquired peculiarity I have no information.

Passing on to Vertebrates we find a striking example among fishes in the case of the Pleuronectidæ, where in some species the right half of the body, in other the left, has assumed a singular superiority over the other. The fish which originally had its dorsal surface upwards and its ventral downwards has turned on its side, developed pigment on what becomes its upper surface and lost it on the lower, and by a peculiar twist of the skull the mouth is brought chiefly to the under side and the visual terminals to the upper. In these fishes the modification may have been due to some geological change in the sea-bed, rendering a bottom habit more advantageous, or to some change either in the food sought or in the enemies avoided, which rendered the bottom habit beneficial. They are found fully developed as far back as the Miocene period.

I, personally, am ignorant of any conspicuous example of asymmetry among Amphibians or Reptiles, and among the Birds they appear to be few. Many birds sleep habitually standing on one leg, but so far as I know (and in this I am supported by the more extensive observations of Dr. William Ogle*), these birds use the right and the left leg indifferently. In the Cockatoo and Parrot tribe, however, there is a preference for the one side; these birds have developed marked prehensile power in the leg, and, for example, in opening a nut, the bird usually stands on the right leg and holds the nut in its left.

The great majority prefer to stand on the right leg, but a few use the left, while holding an object in the other claw.

In Mammalia structure and function are usually symmetrical, but there are exceptions. Where the extremities are used for the simple purposes of support

* Med. Chir. Trans., Vol. liv.

and progression, we should naturally expect no difference in functional activity between the two sides, but, nevertheless, there is some evidence that the right fore and hind legs in the ox, the sheep, and the horse are heavier than those on the left side. In cantering the horse leads off with the right foot; kicking, however, seems to be done quite impartially with right and left; the evidence as regards the preponderance of one side in these animals is as yet, however, inconclusive. Among the Rodents a French naturalist has described definite right-handedness, but I have been unable to obtain the reference. Among Squirrels, Marmots, the Jerboa, the Mouse, and the Rat, I have been unable to satisfy myself that there is any distinct preferential use of either side. Among Carnivora, and especially the Felidæ, the specialised uses of the anterior limb are considerable, thus far, however, in none of them have I seen clear proof of right-handedness. The Bear uses his upper limb for many purposes, but after observing about half a dozen with some care I have failed to discover any preference in the use of the one limb. The Quadrumana shew very marked right-handedness; I have tested a large number of individuals and find them nearly all right-handed, and other observers, as, for example, Dr. W. Ogle,* has noted the same. I have had no evidence of a preferential use of the right hind limb.

It is in the human species that right-handedness is most pronounced. In fact, both right arm and right leg are somewhat larger and more muscular than the left. According to Ogle a little over ninety-five per cent. of English people are right-handed, and nearly five per cent. left-handed. Left-handedness is much more frequent in the male than in the female. Preferential use of the

* *Loc. cit.*

right eye also, commonly accompanies right-handedness, though not always. The right eye and its associated nerve mechanism has usually a higher functional activity than the left, as those who use the telescope or microscope know, as also do the rifle- and artillery-man; not only the power of seeing, but that of observing appears more developed in the right-sided organ.

So far as my experience goes, the senses of touch, taste, smell, and also hearing (apart from its speech relations) are not one-sided. I have tested them in great numbers of persons. Man is not only right-handed, the lower limb participates in the right-sidedness as almost any football player will testify.

As nearly all sensory and motor nerve fibres decussate, it follows that the left brain is associated with the preferential use of the right side; we should consequently expect to find the left hemisphere differing slightly from the right. I think I am correct in stating that, as a rule, the arrangement of convolutions in the anterior lobe of the left hemisphere in a well-developed brain, is more complex than on the right. Moreover, there is no doubt that the faculty of conveying ideas to others by phonetic, visible, or written signs, has developed in man almost exclusively in the third left inferior frontal convolution. And not only does outgoing language such as speech or writing proceed from nerve centres in the left hemisphere, but also those incoming messages which we are constantly receiving by eye and ear; the faculty of comprehending objects presented to the senses also resides usually in the left hemisphere. You and I know that the object I have in my hands at this moment is an inkstand, because in each of us there exists a memory stored in the cells of the angular and supra-marginal gyri of the left brain of inkstands previously seen. Suppose the gyri or the white matter beneath them were destroyed or in any way thrown out of function, then, though you or I might see the object, we should not know what it was, because we should have no recollection of having seen the object or of its use. The condition is called mind-blindness. In a similar way mind-deafness arises from destruction of the superior and transverse temporal convolutions on the left side. A perfectly familiar word addressed to us would in that case be heard, but would convey no meaning. In fact, we right-handed people have got all these memories, the result of a lifetime of observation and reflection, stored in certain parts of our left brain. There is considerable evidence that the left hemisphere is slightly heavier than the right (*vidé* the observations of Dr. Boyd* and of Broca†); Charlton Bastian‡ also found the specific gravity of the grey matter on the left side higher than that of the right.

The speech centre convolutions are usually much more developed on the left side than on the right, while in left-handed men the reverse exists.

The right-sidedness of man has no doubt been increased by artificial means; the child is always taught to use the right hand in writing, drawing, in shaking hands and in many other ways. So far as I have been able to discover right-handedness is the rule with all the races of mankind. It is an interesting question how long this condition has existed. Linguistic evidence shews it to be ancient, the curious association of the dexter hand with intellectual and moral qualities, its symbolism of that which is good, clever, favourable, or happy, occurs

* Phil. Trans. Roy. Socy., 1861.

† Quoted by Bateman, Jour. Mental Science, Oct. 1869.

‡ Lancet, July 8, 1871.

in many languages, while the left has opposite associations. The Latin word *sinister* has a very definite connotation both in Latin and English. The words *scævus* and *læve* meant left, incorrect, wrong. Among the Greeks δεξιός meant right, that which is good, clever, skilful, while σκαιός and ἀριστερός meant left, auguring evil, that which is rude, foolish, awkward, even wicked. Right-handedness is mentioned by Aristotle and Hippocrates; but we can trace it much further back. In ancient Egyptian, Assyrian, and Babylonian Art the pen, the brush, the tool and the weapon are almost always depicted as being carried in the right hand. We may conclude that civilised man has been right-handed for at least 6,000 years.

The question of cause is also interesting. Among the molluscs and crustaceans and probably in the pleuronectidæ, asymmetry has probably followed from an accidental variation, which benefitted the animal by protecting it or rendering the acquisition of food more easy. Being the fittest in its competition with others, it has survived. But how about the asymmetry in parrots, monkeys, apes and man? Dr. Ogle believes the parrot tribe owe their one-sidedness to extra blood supplied to the left brain. He tells us that usually the brain is supplied by only one vessel and that generally goes to the left side. He (as also Dr. Wyeth, of New York*) applies this blood supply theory also to the case of the Quadrumana and Man, he believes that the left carotid artery is usually larger than the right, and also that the blood stream entering the left carotid meets with fewer angles in its course than that of the right. Against this view it may be objected that it is not proven that the left is any larger, and the difference in angle is trivial, nor do the carotids

* Annals of Anat. and Surg. Socy. of Brooklyn, 1880.

present any peculiarity of arrangement in left-handed people.

The theory of M. Acquille Combe* suggests that the fœtus *in utero* rests with its left side pressing against the maternal spinal column, that the pressure interferes with muscle development on the left side. If the fœtus chances to rest in the opposite position the right side is pressed upon and the individual becomes eventually left-handed. An ingenious hypothesis, but it does not cover the cases of the parrots nor of the invertebrates.

Professor G. V. Poore† attributes right-handedness to the extra weight of the viscera on the left side of the thorax in man and some other vertebrates. Professor Struthers,‡ on the other hand, points out that the viscera of thorax and abdomen combined are in man from fifteen to twenty ounces heavier on the right side than the left. He considers this extra weight on the right side has produced a greater development of the right leg, and as a consequence (though I fail to see why) of the right arm also.

A fourth theory regards right-handedness simply as the result of habit founded on accidental variation, which has become a permanent condition through affording certain advantages in the way of protection, etc. In other words we bring it under the same law as the asymmetry of the invertebrates. Dr. Pye Smith¶ has an ingenious hypothesis (improving upon that of Bichat‖) regarding the detailed mode of the production of this habit in man. He thinks that as man is and always has been a combative animal, whose method of fighting, until quite recent times,

* Journal de Physiologie. † Lancet, 10th April, 1897.

‡ Ed. Med. Journal, 1863, and Lancet, 17th April, 1897.

¶ Guy's Hosp. Reports, 1871, p. 141.

‖ 'La Vie et la Mort.'

involved the use of the shield in one hand and spear or sword in the other, he found by experience that wounds on the left thorax, where the heart lies, were more fatal than those on the right, consequently he learnt to hold his shield on the left side and this led to a more active use of the right arm and hand in the wielding of offensive weapons. The condition thus established we may parallel with that of the Mollusc or the hermit crab; Pagurus carries his shield or shell on one side and fights with his hypertrophied limb on the other side. I confess this last view seems to me preferable to those which seek an explanation in extra blood flow, in uterine position, or in visceral weight. Either by the preferred use of weapons in the right hand, or by some other determining cause, man certainly at an early period selected his dexter hand, and when later he began to draw, to sculpture stone or wood, or to inscribe word-symbols he continued to use his right hand and thus fixed the memory of objects or symbols in that part of his left hemisphere whence proceeded the motor impulses.

But before he began to write he had been able to speak and to understand speech; why did the physical substratum of incoming and outgoing speech processes fix itself in the left hemisphere? It is hard to say, unless we suppose that already righthandedness had established a pre-eminent functional activity in the left brain.

Now we come to the final point: Is the pre-eminent functional activity of the left brain, which in one way or other has been established in the human race, still continuing to be beneficial to man, or is it the contrary? The question, to my mind, is one of much difficulty and seriousness. In the case of every other paired organ the functions of right and left seem to be identical, as we see in the lungs, kidneys, sexual structures, sense organs of taste, smell, hearing, touch, heat perception, etc., and in numerous glands. One of the advantages of a duplicate organ lies in the fact that if the one be injured the other remains to discharge its function; it is thus with the lung, the kidney, the glands and sense organs referred to. The man who loses one eye may be very thankful that it is not the single pineal eye of an early period of living things, of which he has been deprived, and that he can fall back upon the other one of the pair. The Brain alone in man has now departed from the observance of this great law. While the functions of its right and left halves remain the same in certain important respects, such as motion and tactile sensibility, the treasury of memory as to objects seen and word symbols heard, the faculty whereby we communicate with our fellows, the hard earned products of education, are almost exclusively stored in the left hemisphere: should any accident happen to certain parts of that important structure the unhappy individual loses the power of speech, the power of understanding speech and written language, he may even lose the recognition of the objects and the persons around him, and the memory of his past life. It seems unwise that we should keep, so to speak, all our intellectual eggs in one basket, when we are provided with two of these marvellously constructed organs. Having these two brain hemispheres, does it not seem probable that we lose much by only educating one?

We don't know much at present about the function of those parts of the right brain which correspond to the important organs in the left, of which I have spoken; they are probably potential language and memory centres, dormant as regards function. Would it be possible to educate them, to locate the language faculty, motor and sensory on both sides? If this were possible the advantages would be great both as regards security from loss and the probable gain in intellectual energy. There is strong evidence that in young persons the destruction of the speech centre in the left hemisphere, while causing loss of the faculty for a time, may be recovered from by the education of the right centre. A case is recorded in which this occurred, and when the centre on the right, which had thus been educated, was, by a strange and lamentable chance itself destroyed, the speech faculty vanished finally. In middle and advanced life recovery of the faculty does not occur. We know that left handed people can be made by education almost ambidexterous, but we don't know yet whether or not in such persons the speech and thought centres develop on both sides; it is quite possible that they do.

These facts render it likely that our present condition as left brained people, while to a large extent fixed by the influence of a long heredity, is not absolute and inevitable; it seems possible that if mankind paid more attention to the right hemisphere by using and training the left hand and eye and by practising the art of writing and drawing with the left hand, we might greatly augment the nerve energy, the power of memory and the intellectual faculty generally of our race, while at the same time lessening the risk which attends over use and over strain of one organ, and also providing a duplicate nerve mechanism as a sort of insurance against the accident of disease.

Unhappily the influence of education and of educators is at present in the main thrown into the other scale. This question is a large, and, I think, a highly important one; it is one on which, in the present stage of knowledge, I do not like to dogmatise too strongly; I leave it for your consideration.

And now it only remains for me to express my thanks to Professor Herdman, to Dr. Forbes, Professor Sherrington, Mr. Clubb and Dr. Grunbaum for help they have kindly given me, and especially to yourselves for the patience with which you have listened to a somewhat discursive and rambling address.

THE NEW BIOLOGICAL STATION AT PORT ERIN.

BEING THE

SIXTEENTH ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE.

This Report, which records the completion and occupation of the new buildings at Port Erin, opens a fresh period in the history of the Liverpool Marine Biology Committee, and so gives a fitting opportunity to summarise past work, take stock of results attained, and discuss some future plans and aims.

Brief History of the L.M.B.C.

The Liverpool Marine Biology Committee was constituted in March, 1885, at a public gathering of the local Naturalists from Liverpool, Manchester, Southport, Chester, and the neighbourhood, summoned by Professor Herdman to meet at University College for the purpose. The declared objects were "to investigate the Marine Fauna and Flora (and any related subject 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." These ends have been kept steadily in view for the last seventeen years.

At an early stage of the investigation it became evident that a Biological Station or Laboratory on the sea-shore nearer the usual collecting grounds than Liverpool would be a material assistance in the work. Consequently in 1887 the Committee established a small Biological Station on Puffin Island, off the north coast of Anglesey, and during the next five years this laboratory was kept up, and constant dredging and other exploring expeditions were carried on, as the result of which the three first illustrated volumes of Reports (" Fauna of Liverpool Bay," Vols. I. to III.) were published. The Puffin Island Station was very useful for a time, as our earlier annual reports abundantly show, and besides serving to educate some of

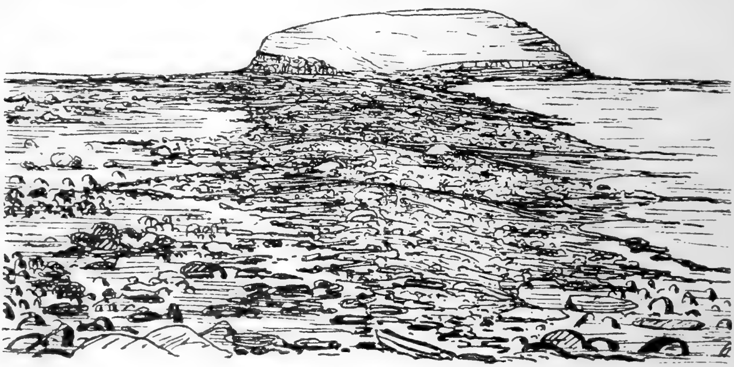


FIG. 1. Collecting ground at Puffin Island.

our senior students and stimulate the local naturalists, it supplied material to a considerable number of specialists, and gave scientific results which were published in the volumes on the Fauna. It came, however, in time to be felt by the Committee that a station in a spot more readily accessible from Liverpool, and not so wholly isolated, would enable the specialists to do more work, and be of more use to students and investigators generally. It was also becoming evident that after five years' work on the shores of the small island (fig. 1), the greater number of the plants and animals had been collected and examined, and that a change to a new locality with a richer fauna and a more extended and varied line of coast would yield an increase of material for faunistic work.

Consequently in 1892, after a preliminary investigation of the south end of the Isle of Man, and encouraged by a most cordial invitation from the Natural History and Antiquarian Society of the

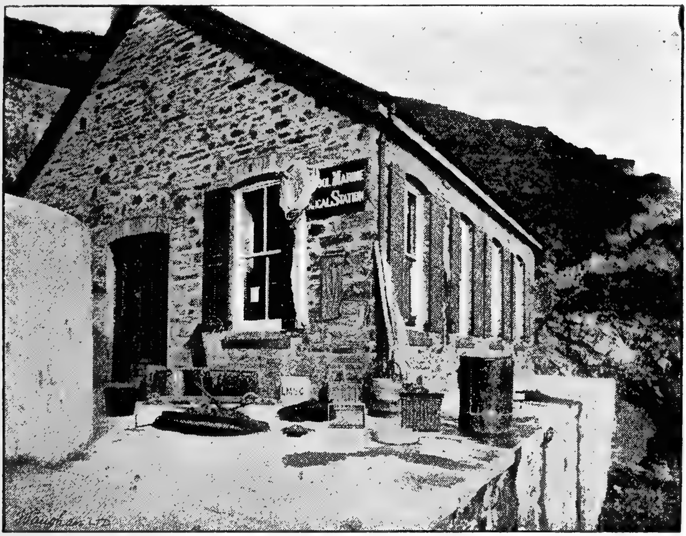


Fig. 2. The old Biological Station at Port Erin—end view of Laboratory.

Island, the centre of the L.M.B.C. field work was transferred from Anglesey to the Isle of Man—"from the Mona of Tacitus to the Mona of Cæsar." Here a small three-roomed biological station (fig. 2) was built on the northern side of Port Erin Bay, and was formally opened for work on June 4th by Sir Spencer Walpole, the Governor of the Island. Our Sixth Annual Report (December, 1892) contains a full account of the opening and the subsequent proceedings. Since that time the Port Erin Station has been conducted without a hitch, and with increasing success, each Annual Report showing fresh work undertaken and further results achieved. In March, 1893, a second building was added to the Station (fig. 3) in order to supply the necessary aquarium tanks for observational and experimental work, and also to enable the public to see something of the wonderful variety and interest of life in the ocean and on the sea-shore. Then followed in a year or two sea-fish hatching, which was undertaken at first on a small scale in the basement, in order to show what could be done in that direction with our local fish and the water of the bay. Later on experimental work with oysters was carried on by Professors Herdman and Boyce, which led to the publication of a Memoir on the subject. Two additional volumes of the "Fauna" (IV. and V.) have since been issued, and a new form of publication, the L.M.B.C. Memoirs, has been started, of which Numbers I. to IX. have now appeared. Ten Annual Reports (the sixth to the fifteenth inclusive) deal with this period, and show, latterly, how inadequate the accommodation has been to the number of workers and the amount of research carried on.

The alliance between a Committee appointed by the Manx Government and the L.M.B.C., which has resulted in the provision of a much larger Biological Station on a better site at the southern side of Port Erin Bay, had its origin in the sea-fisheries work carried out on an experimental scale in the old station for the purpose of obtaining information for the Lancashire Sea-Fisheries Committee. In 1898 an Industries Commission, presided over by the Lord Bishop, recommended that in the interests of the insular fishing industries the

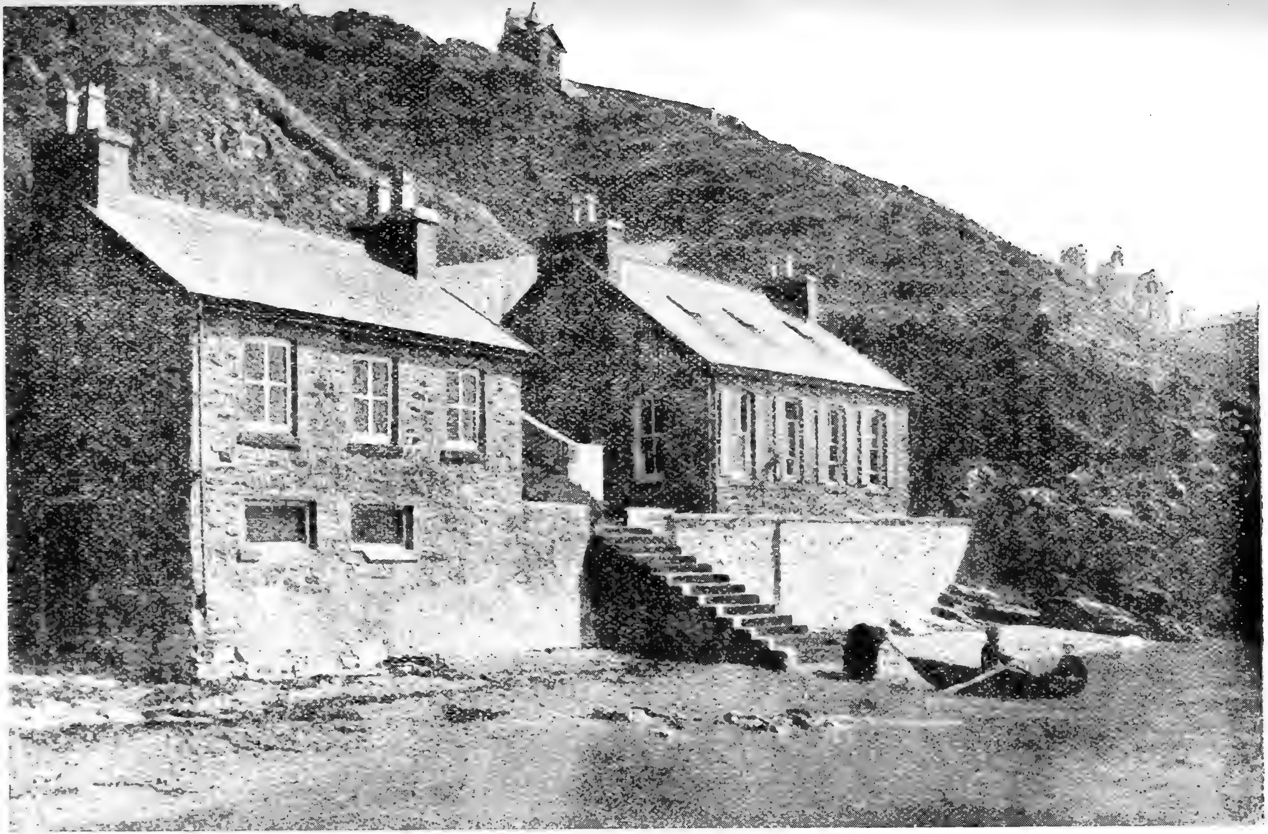


FIG. 3. Front view of old Biological Station, with Aquarium.

D

Government should promote practical fisheries investigations, and for that purpose establish a closer connection with the authorities of the Port Erin Biological Station. A Committee of the Tynwald Court, appointed on 21st May, 1901, met at Port Erin under the Chairmanship of His Honour the Deemster Kneen, on June 16th, took evidence, examined sites, conferred with representatives of the L.M.B.C., and reported in favour of erecting a combined Biological Station, Aquarium, and Fish Hatchery upon a site near the base of the breakwater, and recommended to the Tynwald Court on July 12th that a grant of £2,000 be made for the erection of the building, and that an annual sum of £200 be voted towards maintenance. They also recommended that a Committee be appointed to make arrangements with the Harbour Board as to the site for the necessary buildings and tanks, and also with the Liverpool Marine Biology Committee as to the management of the Hatchery and the use and control of the Laboratory and Aquarium. The Tynwald Court adopted the report, granted the necessary sums, and appointed a Hatchery Committee to take charge of the Manx portion of the institution.

The further business details of the arrangement concluded between the Hatchery Committee and the L.M.B.C. were given in our last Annual Report (p. 25), and need not be repeated. It may suffice to say that the two Committees have worked most harmoniously together, and will no doubt continue to co-operate cordially and usefully. Of the three departments in the institution, the Laboratory block will be wholly under the control of the L.M.B.C., the Hatchery block will belong solely to the Manx Committee, and the Aquarium in the centre will be managed as a joint concern in the interests of both the scientific and economic work.

The Curator of the old Biological Station (Mr. H. C. Chadwick) has become Curator of the whole institution, with a practical fisherman assistant (Mr. T. N. Cregeen) under him, and the Hon. Director and Chairman of the L.M.B.C. is recognised as being Director also of the Hatchery. This should secure unity of aim and economy of working, and will result in the various departments being mutually helpful. The fishery work will be instructive to the scientific students, and the investigations in the Laboratory and experiments in the Aquarium will be useful in connection with fishery problems. The Aquarium, which, with its museum of local marine animals and plants in the gallery, occupies the large central block of the building, is the only part open to the public, and will, it is hoped, be useful alike—

(1) To the scientific workers in the laboratory,

(2) For experiments and observations bearing on fishery questions and practice, and

(3) As an educational influence which will be appreciated by the more intelligent visitors, and may, it is hoped, be taken advantage of by local schools for instruction in nature study. The Committee have already received an application from Mr. Walter R. Teare, of Arbory School, for permission to make use of the institution for this purpose.

Description of the New Biological Station.

The plans of the new building were in the first place drawn up by the Hon. Director, and, after being submitted to both the L.M.B.C. and the Hatchery Committee, were placed in the hands of Mr. Carine, who acted as architect to the Committee, for detailed treatment and the preparation of specifications. The drawings for the internal fittings were made by Mr. Chadwick from Prof. Herdman's

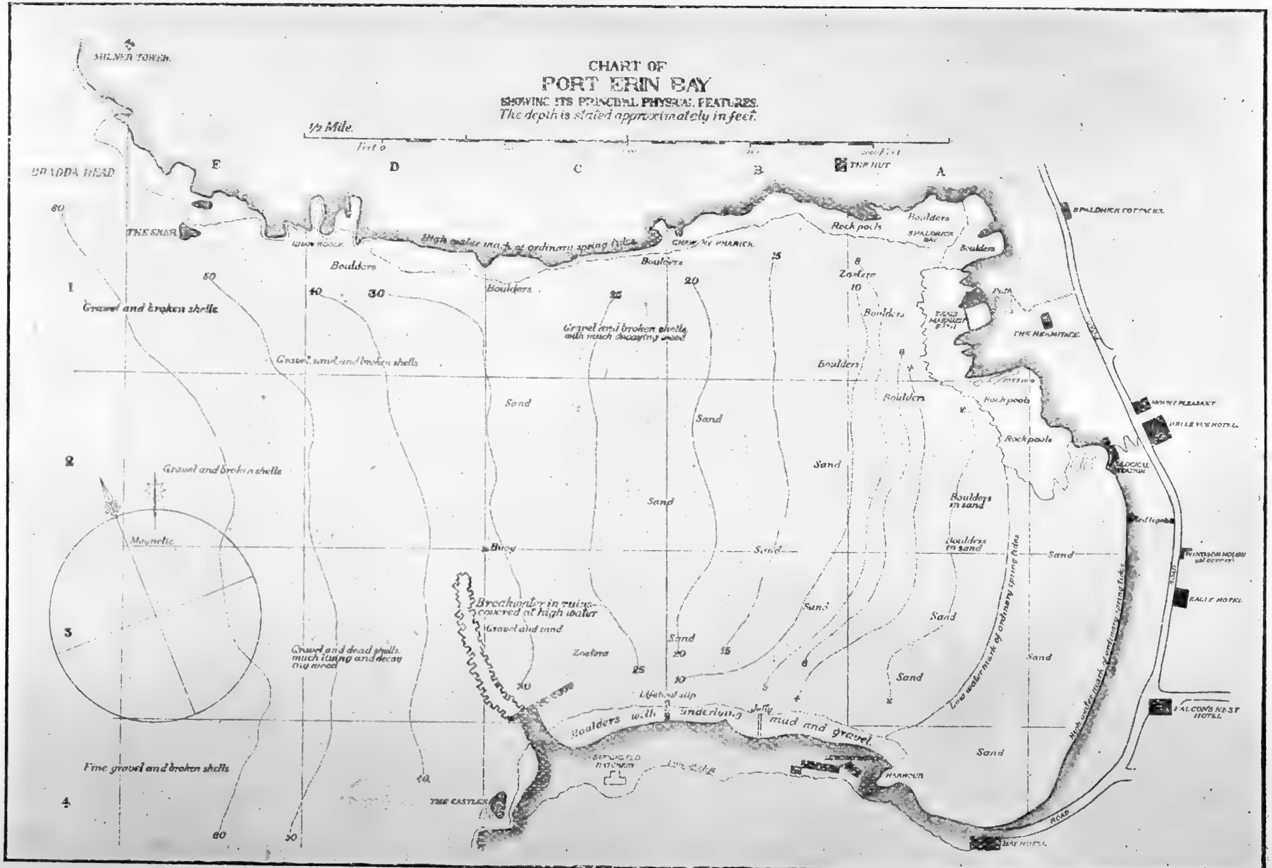


CHART OF
PORT ERIN BAY
SHOWING ITS PRINCIPAL PHYSICAL FEATURES.
The depth is stated approximately in feet.
1/2 Mile.
MILNER TOWER.
BRADDA HEAD
THE SKER
THE HUT
E
D
C
B
A
1
2
3
4
High water mark of ordinary spring tides
Boulders
Rock pools
Gravel and broken shells
Gravel, sand and broken shells
Gravel and broken shells with much decaying weed
Sand
Zostera
Boulders in sand
Low water mark of ordinary spring tides
Magnetic
Buoy
Breakwater in ruins covered at high water
Gravel and sand
Gravel and dead shells much living and decaying weed
Lifeboat slip
Boulders with underlying mud and gravel
Jetty
HARBOUR
THE CASTLES
Fine gravel and broken shells
THE HERMITAGE
SPALDRICK COTTAGES
MOUNT PLEASANT
BELLE VUE HOTEL
Red lights
WINDSOR HOUSE
EAGLE HOTEL
FALCON'S NEST HOTEL
BAY HOTEL
ROAD
Path
Rock pools
Sand
60
50
40
30
25
20
15
10
8
6
5
4

FIG. 4.

rough sketches. The tender of a local firm of builders, Messrs. McArd & Moore, was accepted, and the contracts for the work signed in October, 1901; and the foundations of the building and excavation for the large fish pond were commenced on November 4th. The outside of the building was completed by Easter, but the special fittings of the Aquarium and Hatchery and the installation of engine, pumps and sea-water pipes caused some delay, so that the institution was not ready for occupation until July. Mr. Chadwick finished moving the L.M.B.C. effects

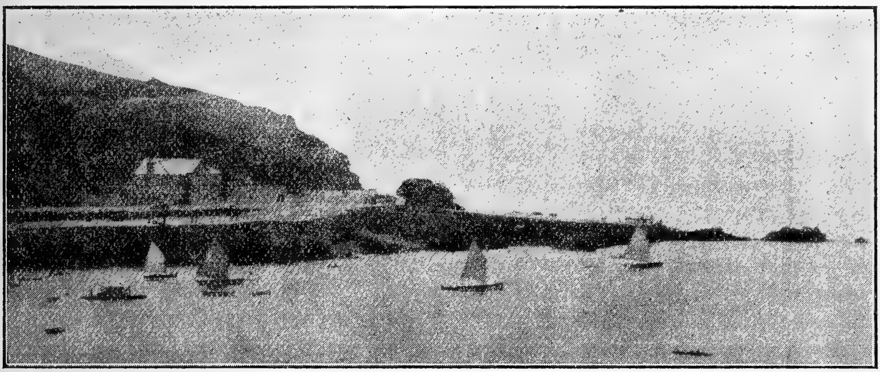


FIG. 5. Port Erin Bay and Biological Station.

from the old station to the new on July 12th, and our first student workers occupied benches in the laboratory during August.

The chart of Port Erin Bay, given as fig. 4, shows in square C.4, under the name "suggested hatchery," the approximate site, but not quite the exact shape of the building. Figure 5 shows the general surroundings of the institution, placed at the base of the cliff, close to the shore, and not far from the ruined breakwater which is a conspicuous feature in all views of the entrance to Port Erin Bay. The larger view (fig. 6) shows the front elevation as a plain but substantial two-storied stone building of nearly 100 feet in length by over 40 feet in breadth, with a light railing in front and a large yard, enclosed by a wall, behind. At the western end (see fig. 7) is a large pond excavated in the rock, measuring about 90 feet in length, nearly 50 feet in

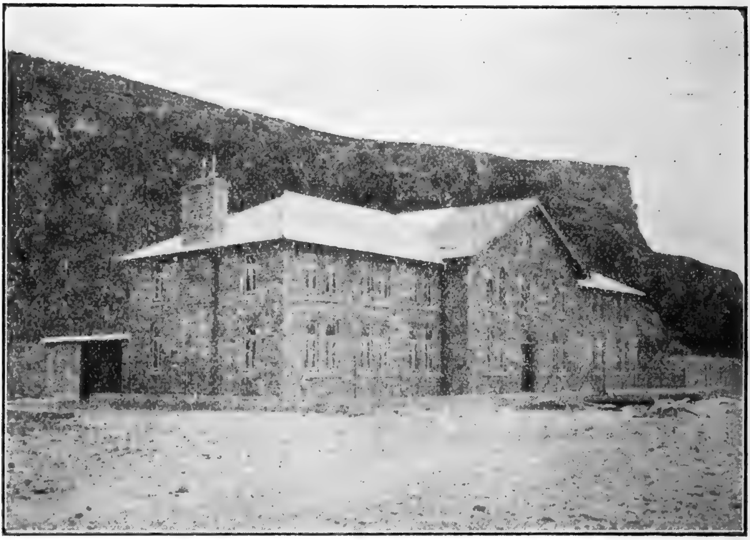


Fig 6. The New Biological Station.

breadth, varying from 3 to 10 feet in depth, and capable of containing about 130,000 gallons of sea-water.

The following description of the building was drawn up by Mr. Chadwick from the building plans (see figs. 8 and 9):—

The new building, the erection of which was begun on November 4th, 1901, consists of a centre block and two wings two storeys in height, and has a frontage of 90 feet. The stone of which it is built is of good quality, and was quarried on the spot. The outside and principal partition walls are 18 inches in thickness, and are everywhere lined inside with a wainscotting of varnished pine wood, which gives the interior of the building a light and pleasing appearance. The entrance hall is situated in the middle

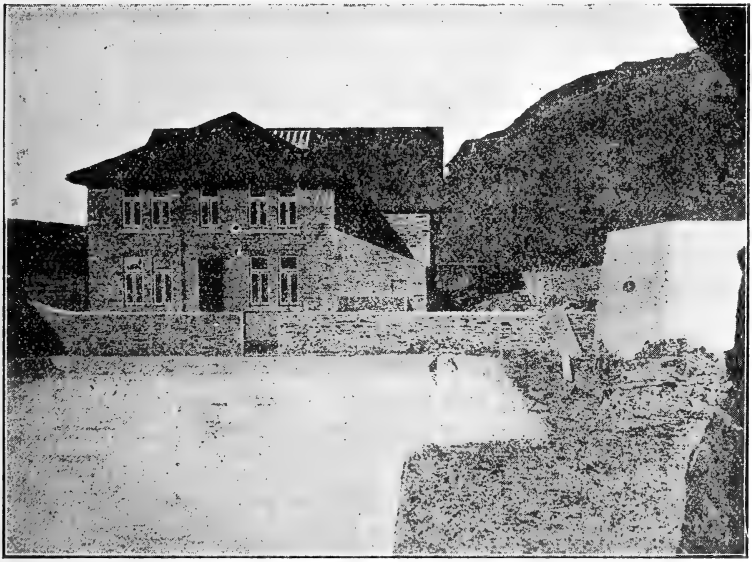


FIG. 7. Western end of Station showing Spawning Pond and Hatchery entrance.

of the centre block, and is 10 feet long by 6 feet wide. On either side of it is a small but fairly lofty room, that on the left being for the use of the Director and Committee, while that on the right is the Curator's laboratory, and has a door with enquiry window opening into it from the hall. At the further end of the latter a wide double door, with glazed panels, opens into the Aquarium, a spacious and lofty apartment, measuring 30 feet by 30 feet, open to the roof and well lighted by large skylights. The floor

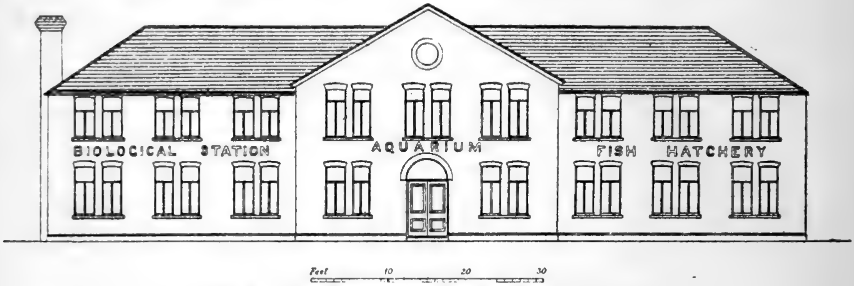


FIG. 8. Front Elevation of Biological Station.

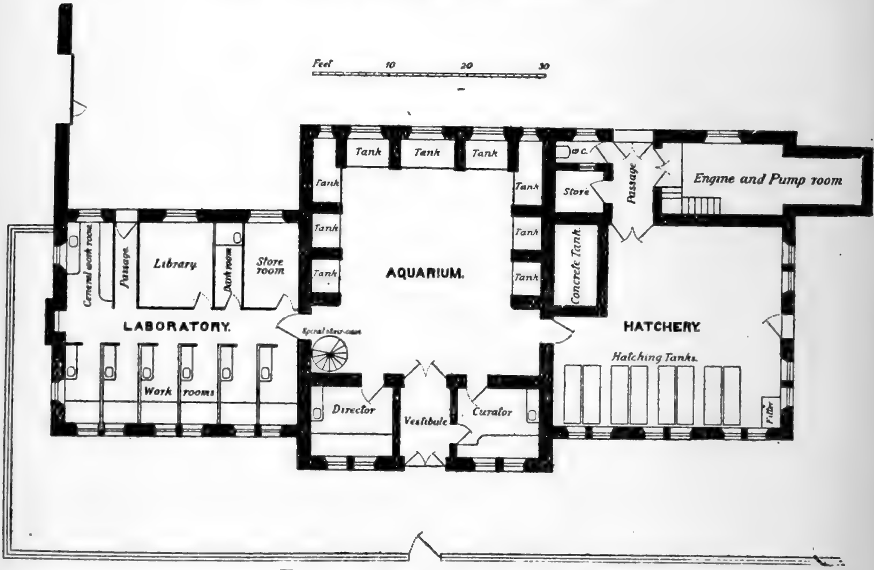


FIG. 9. Plan of Ground Floor.

of the Aquarium is of concrete. The south, east and west walls are occupied by nine concrete tanks, the largest of which measures 7 feet by 4 feet by 4 feet, and occupies the centre of the south wall. The tanks on either side of this measure 6 feet by 4 feet by 4 feet, while those on the east and west walls are of the same depth and width, but only 4 feet 8 inches in length. The fronts of all the tanks are of 1 inch plate glass. Windows in the south wall admit light into the three larger tanks and the two nearest to them on the east and west walls, while the four remaining ones are lighted from the roof, and are provided also with artificial light for use when necessary.

The Aquarium opens into the Laboratory and Hatchery wings by side doors. The door near the north-east corner (fig. 10) affords access to the ground floor of the east wing (L.M.B.C. Laboratories), which is 30 feet long and nearly 26 feet wide. Along the centre runs a passage 4 feet 6 inches wide, with a fireplace at the further end. The space between this passage and the north wall, the six windows of which command picturesque views of Port Erin Bay and Bradda Head, is divided into six workrooms, each of which measures about 5 feet wide by 10 feet long. Each room is furnished with a worktable fixed beneath the window, a side bench with sink, and sea-water and fresh-water taps, a drawer beneath the worktable, and ample shelving. The worktables and side benches are made of Canary whitewood, 1½in. in thickness. On the south side of the passage proceeding from the Aquarium are (1) a room for the storage of re-agents and glassware, (2) a dark room for photography, and (3) the library and writing room, with a small collection of standard works on Marine Biology. A passage, 3 feet wide, leading to a door in the south wall, divides the library from a small room provided with a large sink, benches and shelving, in which the preliminary examination and sorting of specimens obtained by shore collecting and dredging can be carried on in addition to the general work of the laboratory.

The west wing constitutes the Fish Hatchery, access to which is obtained through a door exactly opposite that opening from the Aquarium into the Laboratory. The dimensions are the same as those of the east wing, and the ground floor is of concrete. Along the north or front wall are ranged a series of eight hatching tanks, each of which contains a set of ten hatching boxes, of the pattern devised by Captain Dannevig, of Norway, and similar to those used by the Scottish Fishery Board and the Lancashire Sea-Fisheries Committee. Floor space for four additional tanks has been reserved along the south wall, the remaining space being occupied by a concrete tank built on the floor and measuring 10 feet by 5½ feet by 3 feet. A door in the west wall affords access from the Hatchery to the spawning pond, to be described below, while a wide double door in the south wall opens into a passage, on the left of which are a storeroom and lavatory, and on the right the engine room and pump chamber. The engine is one of Crossley Bros. well-known gas engines, and is of 3 horse-power. The pump is of the three-throw vertical type, built by the same firm, and is capable of raising 4,000 gallons of water per hour.

Returning now to the Aquarium, a spiral staircase of iron at the north-east corner (fig. 10) affords access to a spacious gallery, lighted from above and by windows in the north and south walls. Around the edge an ornamental balustrade of wood supports a series of glazed desk cases for the exhibition of museum specimens. Along the south wall is a bench of Canary white-wood, with cupboards beneath for the storage of herbarium and other specimens. Ample shelving accommodation for the exhibition of spirit and dried specimens has been provided around the walls, while the front side of the gallery forms an apartment measuring 30 feet in length by over 10 feet in width, and lit by six windows facing north, which might, if required, be screened off as additional space for workers.

Doors immediately above those already described as opening from the ground floor of the Aquarium into the east and west wings open from the gallery into the upper floors of the two wings, and another smaller door in the west wall opens into a cloakroom reserved for the use of women students. It is intended to establish apparatus for

FIG. 10. Entrance from Aquarium to the Laboratories.

the hatching and culture of fresh-water fish on the upper floor of the west wing; while the upper floor of the east wing constitutes the junior laboratory, and is furnished with an open bench, and other work-tables, sinks, water taps, &c., and will serve for the accommodation of at least a dozen students. This room contains a firegrate, and having a large open floor area can be used for the occasional delivery of lectures by the Director and others.

At a distance of 20 feet from the west end of the building is a large pond, excavated from the rock, 90 feet long by 50 feet wide, and having a maximum depth along the north side of about 10 feet. This is divided by a partition wall and sluice, and will be stocked with spawning fish, and used also for other purposes. A wall 7 feet high, with rough top, screens the pond from public view on the north and west sides. Against the cliff at the rear of the Hatchery is a tank, built of masonry and concrete, and capable of holding 15,000 gallons of sea-water, for the supply of the Hatchery and Aquarium. Water is pumped from the sea into this tank through a four-inch iron suction pipe, laid in a trench excavated to a depth of about 10 feet below the surface of the ground. The perforated box through which the water enters the pipe is laid on the beach at a point a little below half tide mark, on hard, clean rock, at a place where the water is pure. A low stone wall, surmounted by an iron railing, with a gate opposite the front entrance, encloses an area about 15 feet wide in front of the building. At the west end it joins the wall surrounding the pond, while at the east end it is carried round to the rear of the building, and encloses an area about 5 feet wide. At the same end a substantial stone wall 9 feet high, and having a sliding gateway of the same width, encloses a large and useful yard between the buildings and the high cliff at the back, affording ample room for additional tanks and for the storage of boats, trawls and other gear and apparatus. A glance at figures 8 and 9 will show the front elevation and the arrangement of the accommodation on the ground floor; while figures 5, 6 and 7 show the building and its surroundings from various points of view.

To Our L.M.B.C. Supporters.

In this Report to our own subscribers and workers it is natural, as we stated in the last Report but desire to repeat again, to look at the matter mainly from the point of view of the L.M.B.C., and to feel that the change of site and building is one which offers every prospect of increasing and improving our scientific work. But we desire also to add that our Committee is entering upon the joint undertaking in the most cordial and sympathetic spirit, animated by the desire and the determination to do all that is possible on the part of scientific men to further the aims and objects of the Hatchery Committee and the Manx Sea-Fisheries.

It may be pointed out, finally, that while this change is advantageous to us in giving better accommodation and larger opportunities, it also gives increased labour and responsibility, and in no way relieves the L.M.B.C. of financial burdens. The Liverpool Committee retains its identity and constitution exactly as before, and the subscriptions and special donations from those who are kindly supporting the work will be required fully as much in the new building as they were in the old. The Manx Government subsidy will be entirely applied to the economic work in connection with the local sea-fisheries, and will not be available for the purely scientific work of the Biological Station.

Port Erin and Neighbourhood.

For the information of students and other naturalists who may propose to visit the new Biological Station, we think it well to repeat here a few sentences from our Report of ten years ago, which may give the stranger some idea of the special advantages of Port Erin for the study of marine biology.

Port Erin is at the south-west end of the Isle of Man, and occupies a fairly central position in the Irish Sea, being about 30 miles from Ireland, 33 from Scotland, 40 from Wales and 45 or so from England (fig. 11). The bay

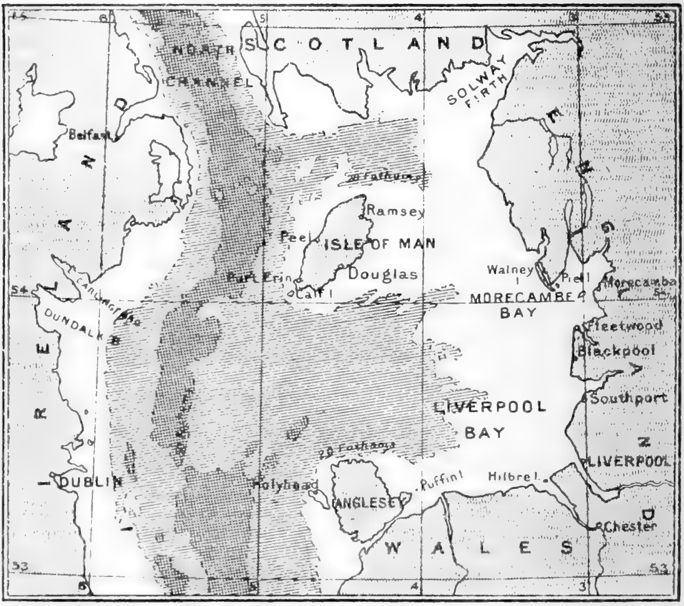


FIG. 11. The L.M.B.C. District of the Irish Sea.

faces nearly due west, and is at most times a good natural harbour with sand at the end and bounded by precipitous cliffs both to the north and south. From its position and the shape of the land, Port Erin has within a distance of a couple of miles in three directions—to Fleshwick Bay, to the Calf Island and to Port St. Mary—a long and varied coast line (fig. 12) with a number of small bays furnishing good collecting ground and shallow water for dredging. Two of these bays, Port Erin and Port St. Mary, have harbours with sailing boats and face in nearly opposite

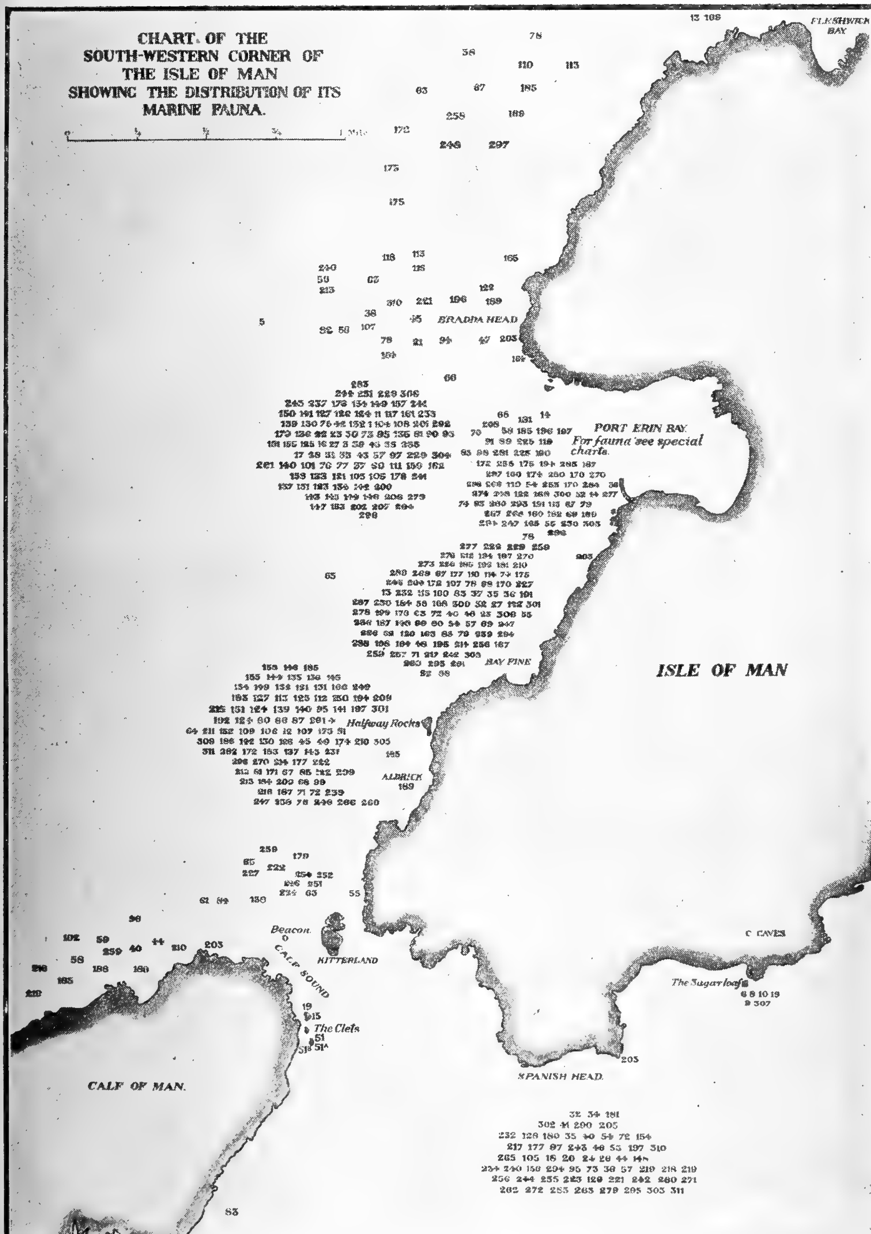


CHART OF THE
SOUTH-WESTERN CORNER OF
THE ISLE OF MAN
SHOWING THE DISTRIBUTION OF ITS
MARINE FAUNA.
FLESHWICK BAY
BRADDA HEAD
PORT ERIN BAY.
For fauna see special charts.
BAY FINE
ISLE OF MAN
Halfway Rocks
ALDRICK
Beacon
CALF SOUND
KITTERLAND
The Clets
C. CAVES
The Sugar loaf
CALF OF MAN.
SPANISH HEAD.

FIG. 12.

directions, so that in most winds one or other is sheltered and has a quiet sea.

The rich fauna round the Calf Island and off Spanish Head (fig. 13) is within easy reach; while at a distance of three to four miles from the Biological Station are depths of 20 to 30 fathoms, and at 14 miles 60 to 70 fathoms depth is found (see fig. 11).

FIG. 13. The Sugar Loaf Rock near Spanish Head.

Although Port Erin is a considerable distance from Liverpool, still it is reached by a regular service of swift steamers and convenient trains, so that there is no great uncertainty or delay in the journey. The 11.30 a.m. steamer from Liverpool to Douglas generally catches the

3.50 train in summer, and the 5.30 in winter, arriving at Port Erin in each case an hour later. In the season, at least two steamers in the day leave Liverpool, and there are also boats from Fleetwood and Barrow; while on holiday occasions there may be as many as five steamers in the day from Liverpool to Douglas. By a 10.30 a.m. steamer from Liverpool in summer it is generally possible to arrive at Port Erin about 3 o'clock in the afternoon. On returning one generally leaves Port Erin at 7 in the morning, arriving in Liverpool about 1 p.m.

Port Erin is well supplied with hotels and lodging-houses, where comfortable quarters can be had at various rates. Those who propose to work at the Station can generally obtain useful information as to lodgings on consulting Mr. Chadwick, the Resident Curator.

University and Other Students.

Of the six small workrooms or alcoves off the laboratory on the ground floor, four are now permanently allotted as follows:—The first, beginning at the eastern end of the building, to the L.M.B.C. workers; the next to students from the Owens College, Manchester; the third to students from University College, Liverpool; and the fourth to those from the University of Birmingham—leaving two places still vacant, in addition to the junior laboratory upstairs which will be used for special classes and meetings, by no means too much room when we contemplate our future work and the demands that will probably be made next year for accommodation.

Last April a very good students' Easter party was managed most successfully by the Curator in the unavoidable absence of all members of the Committee. Professor Herdman was in Ceylon, Mr. Thompson on the Riviera, and Mr. Cole, who was to have had charge of the party, was unfortunately prevented from coming at the last moment. Favoured by beautiful weather every item of Mr. Chadwick's programme was carried out without the slightest hitch. Shore-collecting and tow-netting excursions were engaged in almost daily by every member of the party, the caves at the Sugar-loaf Rock and other more distant points were visited, and much valuable material was collected and preserved for study.

The Station Record.

During the past year the following naturalists and students have occupied workplaces at the Biological Station, in addition to the Curator (Mr. Chadwick), who has been in constant attendance with the exception of his usual holiday in the first half of June.

Date.	Name.	Work.
March 29th to April 12th	Dr. O. V. Darbishire, Manchester...	Marine Algæ.
March 29th to April 5th	Mr. W. Gunn, Liverpool ...	General.
March 29th to April 5th	Mr. W. Burton	Marine Algæ.
April 1st to April 10th	Mr. J. Pearson, Liverpool ...	General.
April 1st to April 15th	Mr. W. Tattersall, Liverpool ...	General.
April 5th to April 14th	Miss Pratt, Manchester... ...	Alcyonium,
April 5th to April 14th	Miss Drey, Newnham	General.
April 11th to April 15th	Mr. Laurie, Oxford	General.

DATE.	NAME.	WORK.
May 17th to May 20th	Prof. Herdman ... ... Mr. I. C. Thompson ... ... Mr. R. Okell ... ... Mr. P. M. C. Kermode ... ... Mr. W. Archer	Official.
July 19th to July 21st	Prof. Herdman ... ... Mr. I. C. Thompson	Official.
July 19th to July 24th	Mr. A. T. Watson, Sheffield ...	Polychæta.
August 8th to August 30th	Mr. C. J. Thompson, Birmingham	Cœlentera.
August 13th to August 28th	Mr. H. A. Whitcombe, Birmingham...	Cœlentera.
August 16th to August 22nd	Mr. A. D. Imms, Birmingham...	Marine Insects.
August 18th to September 1st	Miss Hager, Manchester ...	General.
August 28th to August 30th	Prof. C. B. Davenport, Chicago	The genus Pecten.
September 27th to September 30th	Prof. Herdman ... ... Mr. I. C. Thompson ... ... Mr. A. Leicester ... ... Mr. A. T. Watson ... ... Mr. P. M. C. Kermode	Official.
November 22nd to November 24th	Mr. I. C. Thompson ... ... Mr. R. Okell ... ... Prof. Herdman	Official.

There have also been, as usual, visits from several scientific men and others, including Professor McFarland, of Stanford University, California; Professor Matsubara and Mr. Migousaki, of the Imperial Institute of Fisheries, Tokio, Japan; and the Isle of Man Natural History Society held a meeting at the new Biological Station in September, at which Mr. P. M. C. Kermode presented the bust of Professor Edward Forbes, the Manx Naturalist, to the L.M.B.C. (see further account below).

The Curator's Report to the Committee will be printed at the end as an appendix, but we may note one or two items of interest from it:—The interest in the work of the station aroused in the minds of the local fishermen by the erection of the new building has resulted in the presentation of several of the rarer fishes, amongst which are three new to our collection, viz., Yarrell's Blenny (*Carelophus ascanii*), caught in a crab-pot in March, and

FIG. 14. A low spring tide at Port Erin with *Laminaria digitata* and *Fucus serratus* exposed.

on the shore in May, the "Gattorugine" (*Blennius gattorugine*) in May, which we kept alive for some weeks in the Aquarium and the Tommy-Noddy (*Raniceps raninus*), caught on a line in June.

We have also to thank Dr. and Mrs. H. Bailey, of Port Erin, for their kindness in presenting various specimens of living animals collected in Port Erin Bay. **Figure 14** shows the rolling Laminaria at dead low-water at one of the best collecting grounds in the neighbourhood.

By the beginning of July the new building was sufficiently complete to allow of the removal of the instruments, books, re-agents, tanks and other effects from the old laboratory. The gas engine and pumps were in working order by the beginning of June, but the large storage tank was not completed and filled with sea-water by our pumps until the middle of August. The large sheets of plate-glass for the nine wall-tanks of the Aquarium were cemented in early in August by the Curator, and these show aquaria were filled with water for the first time about August 20th. After that the stocking with animals began, the first fish were introduced early in September, and at the time when the Isle of Man Natural History Society visited the Station on September 27th, the tanks were occupied by about 20 species of fish, all in healthy condition. The Biological Station was opened to visitors for the first time on August 4th, the Curator charging one penny for admission. The first visitor came at 10.15, and by 12.15 thirty-one had paid, between 2.15 and 4.45 p.m. eighty more came, making a total of one hundred and eleven for the day.

Notes on Work Done in the District.

As usual, Mr. Andrew Scott has been indefatigable during the past year in adding fresh records to our knowledge of the animals of this part of the Irish Sea. His list is as follows:—

Trematoda.—*Callicotyle kroyerii*, Diesing, from the cloaca of *Raia clavata*, recorded in last Annual Report as "Trematode sp.;" *Microcotyle labracis*, Van Ben. and Hesse, from the gills of a Bass (*Labrax lupus*) caught off Piel, July 20th, 1892; *Diplectanum æquans*, Diesing, from the gills of the same *Labrax*—the last two parasites are apparently new to Britain. *Leucithodendrium somateriæ* (Levinsen), in the mantle, etc., of the common mussel, *Mytilus edulis.*

Crustacea, Isopoda.—*Pseudione hyndmanni* (Bate and West.), male and female, on a small *Eupagurus bernhardus*; *Pleurocrypta hendersonii*, Giard and Bonnier, male and female, on *Galathea dispersa* (the *Eupagurus* and *Galathea* were from trawl refuse collected near Bahama light vessel); *Phryxus abdominalis* (Kr.), male and female, on *Pandalus montagui*, dredged in channel off Piel, August, 1902.

Crustacea, Copepoda.—*Mesochra propinqua*, T. Scott, and *Canthocamptus parvus*, T. and A. Scott—both species in washings from mud, vicinity of Piel, August, 1902; *Caligus scombri*, B. Smith, from gill chamber of Mackerel, caught off Walney, August, 1902; *Caligus labracis*, T. Scott, from gills of *Labrus mixtus*, caught at Bardsey Island, June, 1902, &c. (recorded in last Annual Report as "*Caligus* sp."); *Dichelestium sturionis*, Kr., from gill chambers of a Sturgeon caught in the salmon nets, river Leven, near Ulverston, July 19, 1902—the fish was a female and measured eight feet in length, the head was given to me by Mr. Broadbent, fishmonger, Barrow; *Haemobaphes cyclopterinus* (Fabr.), from gills of *Cottus scorpius*, caught at Bardsey Island, June, 1902; *Lernanthropus kröyeri*, Van Ben., one specimen from gills of the Bass referred to above—apparently new to Britain; *Charopinus ramosus*, Kroyer, from gills of *Raia clavata*, and *Raia circularis*, Off-shore Station between Lancashire and Isle of Man, April, 1902.

Crustacea, Rhizocephala.—*Peltogaster paguri* (Rathke). There is a specimen of this species, attached to the abdomen of *Eupagurus bernhardus*, in the Zoological Museum of University College, which was dredged during the L.M.B.C.'s first year of work, 1885, probably from about

Hilbre Swash. The species has also occurred this summer amongst material collected by the hopper "Beta," by permission of the Sea-Fisheries Committee, for the Liverpool Museums Committee, from the "Deposit Ground" in Liverpool Bay.

FISHES.—*Callionymus maculatus*, Bonap.—Spotted Dragonet. A specimen of this fish was discovered in the jar containing *C. lyra* in the Fisheries Collection at University College. The exact date and locality of capture are doubtful, but this is certain that it was taken somewhere off the Lancashire coast, probably off the mouth of the Mersey, about six years ago. Specimens of this Dragonet were also obtained by the hopper "Beta" in the vicinity of the "Deposit Ground," while fishing last summer with a small meshed net by special permission of the Scientific Department of the Local Sea-Fisheries Committee. *C. maculatus* has already been recorded from various places along the British coasts, but not from the Irish Sea. It is probable that the use of a small meshed trawl on suitable areas in other parts of the Irish Sea would bring to light other fishes such as *Gadus esmarkii* and *Lumpenus lampetriformis*, which have occasionally been taken with the shrimp trawl in the Clyde area.

Raia fullonica, Linn.—Fuller's Ray. Specimens of this Ray were found amongst the material collected by the fisheries steamer "John Fell" for the fishermen's classes at Piel this year. One was obtained from Cardigan Bay, and another from the Off-shore station between Lancashire and the Isle of Man, in April, 1902.

It may be noted that the capture of at least four Sturgeon in the Liverpool Bay area have been recorded in the Lancashire papers during the year—two from the River Dee, in June; one from the River Leven (referred to above), in July; and one from the vicinity of Fleetwood, in the last week of October. The head of the specimen from the Leven is now in the Zoological Museum at University College, Liverpool.

Figures 14, 15 and 16 show three of the now large series of photographs of living Algæ, both on the rocks and under the microscope, made by the Rev. T. S. Lea, who proposes to continue his work at the new laboratory during next summer.

FIG. 15. *Himanthalia lorea*, showing the button-like fronds and the thong-like fructification.

FIG. 16. *Delesseria hypoglossum*, magnified.

Professor Charles B. Davenport, of the University of Chicago, paid the Biological Station a visit at the end of August, with the view of collecting material for the work on which he is engaged dealing with the study of variation in the genus *Pecten*. Since then he has been supplied with a stock of specimens from Port Erin.

Mr. Arnold T. Watson, during one of his visits, prepared and mounted for the Museum a choice exhibit of Annelide tubes, upon the mode of building of which (as shown for example in fig. 17) he has written several important papers. These specimens have been put in one of the desk cases on the rail of the gallery which has been

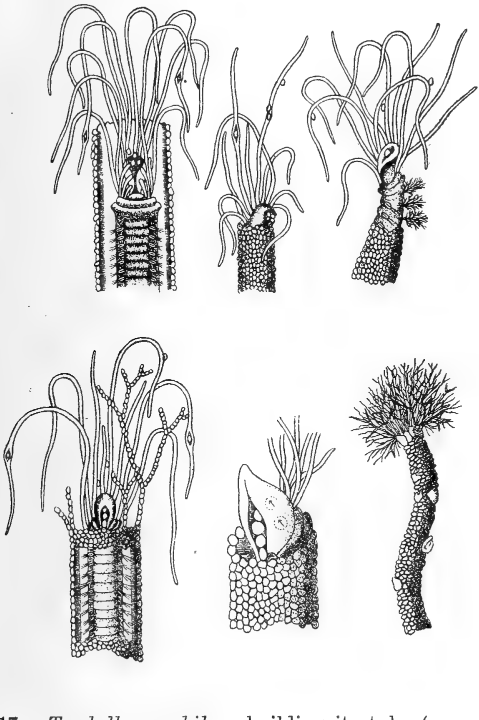


FIG. 17. *Terebella conchilega* building its tube (according to the investigations of Mr. A. T. Watson).

devoted to worm tubes. We propose to allot these glass-topped cases to such special subjects, and to invite our naturalist members of the Committee and other specialists to be good enough to take charge of them during their visits to Port Erin, and to arrange and label the exhibits in their own way. We are convinced that it is only in this manner, by enlisting the voluntary services of those who make a special study of a subject, and inducing them to co-operate in displaying the results of their expert knowledge to the best advantage before the public, that modern museums of Natural History can be brought up to date and made both interesting and of real educational value.

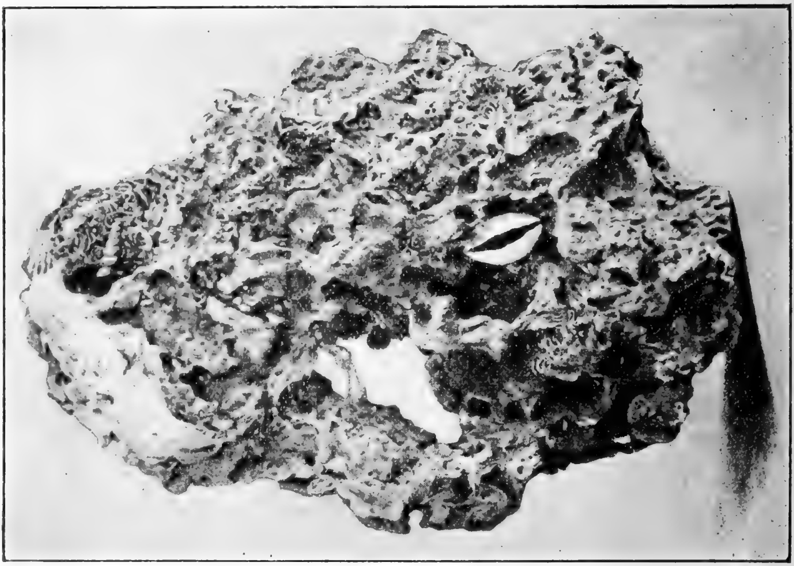


FIG. 18. Calcareous concretion from the sea-bottom containing modern shells.

The antiquarian remains found in the Neolithic Circle on the Meayll, being of considerable local interest, are also exhibited in one of the cases in the gallery. In another we are forming a collection of characteristic deposits, or sea-bottoms, illustrating a subject of both scientific and economic importance. Figure 18 shows one of our most remarkable specimens, a calcareous mass found in deep water between the Calf Island and Holyhead, cementing together the dead shells and sand grains of the sea-bottom.

Mr. A. D. Imms, who eighteen months ago was our first occupant of the University of Birmingham workplace, has paid a second visit to Port Erin, and has sent in the following brief report upon his work:—

"Upon the nomination of Professor T. W. Bridge, I was enabled to occupy the University of Birmingham table at the Biological Station for a short period in the middle of August, 1902. My time, as in my previous visit, was devoted in the main to general Biological work. I also, however, gave some attention to marine insects. I have to record the occurrence of *Clunio bicolor*, Kieff., a Dipteron of the family Chironomidæ, which is new to the fauna of Great Britain. The males were fairly abundant about the surface of the rocks and tide pools at Port Erin, and a few were also observed at Fleshwick. I was fortunate enough to secure a single example of the female, which has hitherto remained quite unknown. In general shape she is vermiform, the legs are very short, the abdomen is bulky and unwieldly, and the wings are completely atrophied. She was taken resting upon the surface film of the water. The Chironomid larvæ mentioned in my report for last year almost certainly belong in part to this insect, and in part to a species of *Chironomus*. Those of the *Chironomus*, in their younger stages, are practically indistinguishable from the larvæ of *Clunio*, and, until I had received adult examples from Mr. Chadwick, I regarded them all as belonging to the latter genus."

Mr. Imms has also prepared a paper giving a description of the Diptera upon which he worked, and this will be read before the Liverpool Biological Society during the present session.

A large Nemertine worm found at Port Erin was submitted to Mr. R. C. Punnett, of Cambridge, who considers that the species is probably new to science. A Campanularian Hydroid, which has been lying unnamed since 1895, when Mr. Chadwick found it, has been identified by Mr. E. T. Browne as *Campanularia calceolifera*, Hincks. Mr. Browne writes in regard to it: "Hincks has given a very good description and figures of this species, and I have really nothing to add. The remarkable shape of the gonothecæ should at once attract attention; so that it must be a very rare species, otherwise there would have been more records of its occurrence. It is not mentioned in Allen and Todd's recent Report on 'The Fauna of the Salcombe Estuary.' Salcombe and the Isle of Man are the only two places where it has been found. The Port Erin slide is at present unique."

The Sea-Fisheries Work.

As the economic wing of the building is not under the control of the L.M.B.C., and as a separate report upon the fisheries work carried on at the Station will be drawn up by the Hatchery Committee, it is unnecessary to discuss that side of the work here. But since the report of the Hatchery Committee will not be issued until July, it may be well to state now (1) that the fittings and apparatus of the hatchery are in a well advanced condition, and will be practically complete before the end of the present year, (2) that a stock of adult plaice is now being laid in to supply spawners, and (3) that there seems every reason to believe that the institution will be ready for active work during the coming spawning season. After fishes have been dealt with lobsters will be taken up, during the summer, and it is hoped that much needed assistance may be given by our operations to an important local industry. In this connection it may be added that the undersized crab and lobster question seems to require investigation and discussion in the Isle of Man, possibly with legislation in view. There can be little doubt but that regulations as to the crabs and lobsters that it is proper to catch would ultimately result in benefit to the fishery, and any size limits determined on should, if possible, be not less than those enforced in the Lancashire and Western District, which covers the fisheries of eight maritime counties.

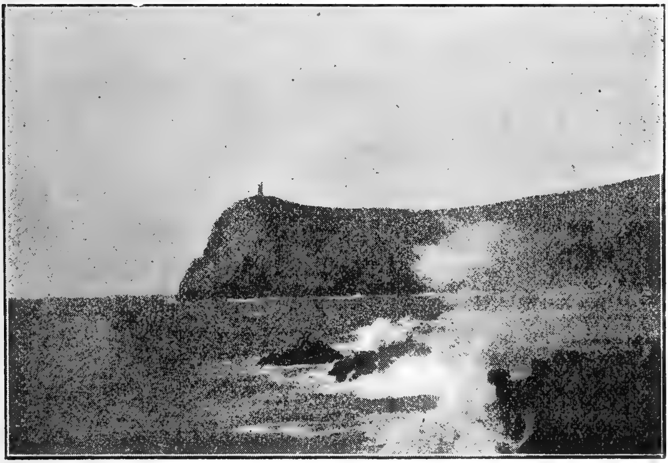


FIG. 19. The rocky shores of Port Erin, where the Lobster and Crab Pots are set.

The majority of the fish we eat from the sea (with the exception of the Herring) produce, in enormous quantities, eggs that are very minute and transparent and which float freely in the open sea. These are known as "pelagic," and the eggs of Cod, Haddock, Whiting and their relations, and of Sole, Plaice, Flounder and other related flat fish are of this kind. It is these pelagic eggs of our most important food fishes that can be obtained in millions at the spawning season, and can be hatched artificially in sea-fish hatcheries, and so may be kept and protected during the first few days or weeks of their existence when they would otherwise be exposed to innumerable enemies in the surface waters of the ocean.

But it cannot be too emphatically stated, and widely made known, that sea-fish hatcheries ought not to be merely for the purpose of hatching young fish and then setting them free in the sea. *Hatching and Rearing* of fish is the end to have in view, and scientific men who have charge of fish hatcheries will not be content till they have succeeded in rearing into young fish, at a reasonable cost, a large proportion of the fry which they can now hatch from the eggs by the million. Professor G. O. Sars first showed how the eggs of an edible fish (the Cod) could be hatched in small numbers as a laboratory experiment; Dannevig in Norway and the U.S. Fish Commission in America have devised the apparatus and technique by which it has become possible with very slight mortality to hatch out such eggs on an industrial scale by hundreds of millions. The next advance must be in rearing. At present practical difficulties block the way, but the Fishery Board for Scotland has had some success with Plaice, and the French at Concarneau with the Sole, and we cannot doubt that further investigation and experience will show us the best methods to pursue. It is at institutions like this at Port Erin, where a Scientific Laboratory is combined with the Hatchery, that experiments in feeding and aeration can be carried out which will eventually lead us to the successful rearing of the young fish that we now hatch and distribute as fry.

Inspection of the New Station.

On account of the delay in the completion of the large spawning pond (which had caused the Hatchery

Committee to postpone any formal inauguration of the institution until some future occasion) and the desire which was expressed by the Isle of Man Natural History and Antiquarian Society to visit the Station, the L.M.B.C. decided to hold a meeting at Port Erin on September 27th, to which the local naturalists could be invited for the purpose of inspecting the Biological Laboratory and Aquarium. This meeting also afforded an opportunity for the L.M.B.C. to receive from Mr. P. M. C. Kermode, of Ramsey, the bust of the late Professor Edward Forbes, the eminent Manx Naturalist, which Mr. Kermode had had prepared for presentation to the new Biological Station. The bust, which is an excellent life-size replica of the well-known marble head of Forbes in the Government Buildings at Douglas, was cast by Mr. Royston, of Douglas, and has been placed on a shelf-pedestal projecting from the front of the gallery in the centre of the Aquarium, opposite the main entrance. Figure 20 shows the appearance of the bust as seen in a photograph taken by Mr. A. Petrie Watson, to whom we are also indebted for the photographs from which figures 5, 6 and 7 were produced.

The following account of the proceedings at the meeting on September 27th is abbreviated from the reports in the Manx newspapers:—The party assembled at noon at the Biological Station. The Acting Governor (Sir James Gell), Deemster Moore, Canon Kewley, the Rev. C. H. Leece (President of the Society), and a number of other officials and members were present, along with visitors from Port Erin, and these were met by Professor Herdman, Mr. I. C. Thompson, Mr. A. Leicester, Mr. Arnold Watson, Mr. Kermode and Mr. Chadwick, on behalf of the L.M.B.C., and were conducted to the Aquarium. There Professor Herdman gave an address of welcome, in which, after describing the three parts of the building and the uses to which they would severally be put, he referred to the educational value of an aquarium, and the use that might be made of it by school teachers and others interested in nature-study. He ended with an appeal to the young people of the Island to take up the study of some branch of Natural History either as a recreation or more seriously, with the view to adding something to the

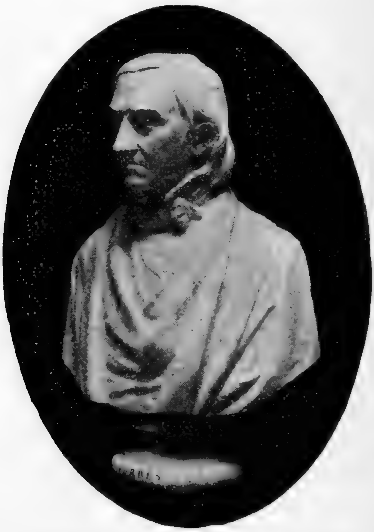


FIG. 20. Bust of Professor Edward Forbes (1815-1854), at Port Erin.

work commenced in that district by Edward Forbes. The President of the Society (Rev. C. H. Leece) replied, thanking the L.M.B.C., and complimenting the Manx Government upon the Institution they had erected, and then called upon Mr. Kermode to make his presentation.

Mr. P. M. C. Kermode formally handed over the bust of Edward Forbes to the L.M.B.C., in the course of a speech in which he recounted the pioneer work which

Forbes had done in connection with the Natural History of the Isle of Man over seventy years before. Mr. Isaac Thompson, as Hon. Treasurer of the L.M.B.C., received the gift, thanked Mr. Kermode, and discussing the requirements of the new Station, pointed out the need of scientific books for the library.

The Acting Governor (Sir James Gell), in thanking Professor Herdman for his address, expressed his approval of the institution, his gratification at the action of the Manx Government in supporting it, and his recognition of its educational value, which he hoped would be taken advantage of by the young people of the Island, and appreciated by the general public.

At the conclusion of the formal proceedings the visitors were conducted round the building by the members of the L.M.B.C., who described the specimens in the tanks, in the Museum and under the microscopes in the laboratory. After lunch at the Belle Vue Hotel, the party visited the Neolithic settlement and circle of stone cists on the Meayll hill, and then returned to the Biological Station for afternoon tea on the invitation of Mrs. Herdman.

It is gratifying to find that since that meeting several enquiries have been made as to possible arrangements for utilising the Aquarium for nature-study by teachers, and the Committee are now arranging, in conjunction with the Liverpool Teachers' Nature-Study Club, to hold a class in the laboratory next Easter, especially for teachers, the details of which will be given in Appendix C at the end of this Report. Such classes have been proposed several times in the past, when difficulties of accommodation and of ways and means, now happily overcome, always stood in the way; but we have on several occasions had visits from teachers with their pupils, and fig. 21 recalls one of those occasions on which the L.M.B.C. arranged a demonstration for the boys of King William's College who were studying Natural Science.

It is interesting also in this connection to notice in the American papers that at the formal handing over (on

FIG. 21. Party from King William's College with the L.M.B.C. at Port Erin.

October 31st) by New York City, of the well-known Aquarium in Battery Park to the Zoological Society of New York, great stress was laid by distinguished speakers upon the educational aspect. "The possibilities of an Aquarium as an institution for the instruction of the people have never been properly understood." "What we want is to make it a part of the City's educational system." "It should be a place for study and investigation." "Fish culture is fast becoming a profession." "We shall

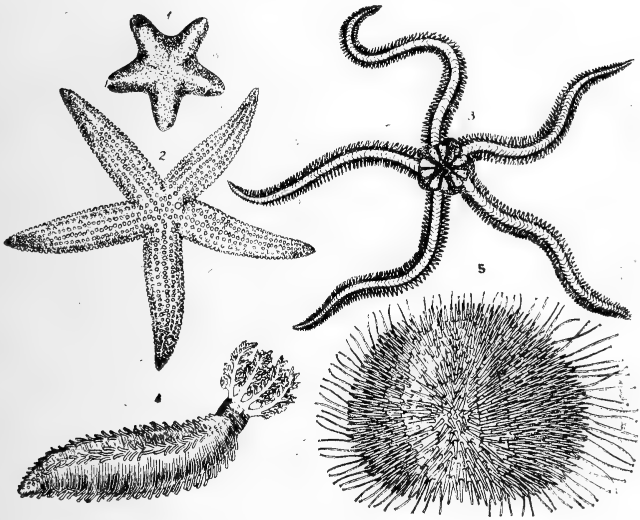


FIG. 22. Echinodermata.

1 *Asterina gibbosa.* 2 *Asterias rubens.* 3 *Ophiothrix fragilis.* 4 *Cucumaria planci.* 5 *Echinus esculentus.*

establish a fish hatchery in the building." "Our determination is to increase not only the attractiveness, but the educational value of the Aquarium to the masses of the people who visit it," are some of the sentences that occur, and which sound like a welcome echo from across the Atlantic of the views which have been expressed at Port Erin by the Liverpool Marine Biology Committee.

It has become evident to us, both from our own experience in our former small Aquarium, and also from the history of other similar but larger institutions elsewhere, that much public interest can be excited and much useful educational work accomplished by well-arranged and adequately stocked and properly kept marine tanks,

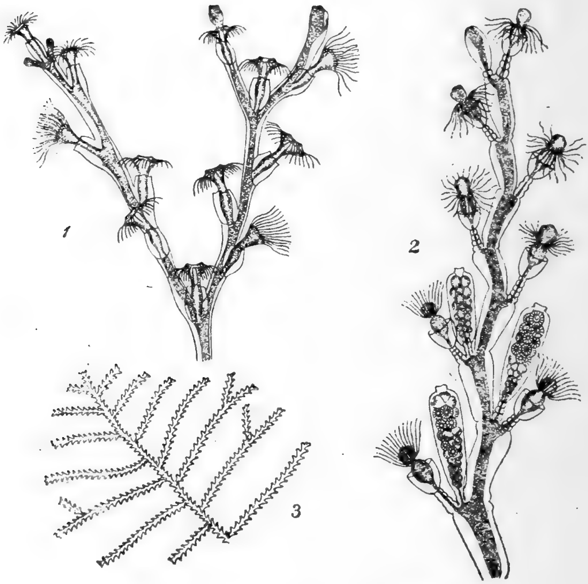


Fig. 23. Hydroid Zoophytes.
1 *Sertularella polyzonias.* 2 *Obelia geniculata.*
3 *Sertularia abietina.*

especially if combined with scientific guidance and personal exposition. The latter, however, although very desirable, is not absolutely necessary, and is not always possible, as it sometimes makes too severe a strain upon the limited time that the Curator can spare from his other duties. It is hoped by the Committee that the "Guide to the Aquarium,"* drawn up by the Hon. Director, with illustrations by the Curator, which we published last year as an Appendix to the Annual Report, and which gives

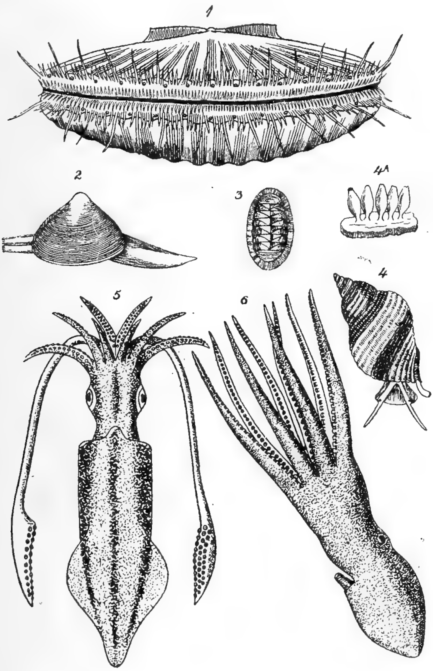


FIG. 24. Mollusca.

1 *Pecten maximus.* 2 *Mactra truncata.* 3 *Chiton lævis.* 4 *Purpura lapillus.* 4A *Purpura egg capsules.* 5 *Loligo vulgaris.* 6 *Eledone cirrhosa.*

scientific facts in popular form and simple language, with numerous illustrations in the text, will enable visitors to the Aquarium to study the living animals of the tanks and

* Can be obtained from the Curator, at the Aquarium, Port Erin, price threepence.

the specimens in the Museum for themselves with intelligent interest, to recognise representatives of the leading groups of marine animals, and to make some acquaintance with the nature and range, the beauty and the importance of the living things of our seas.

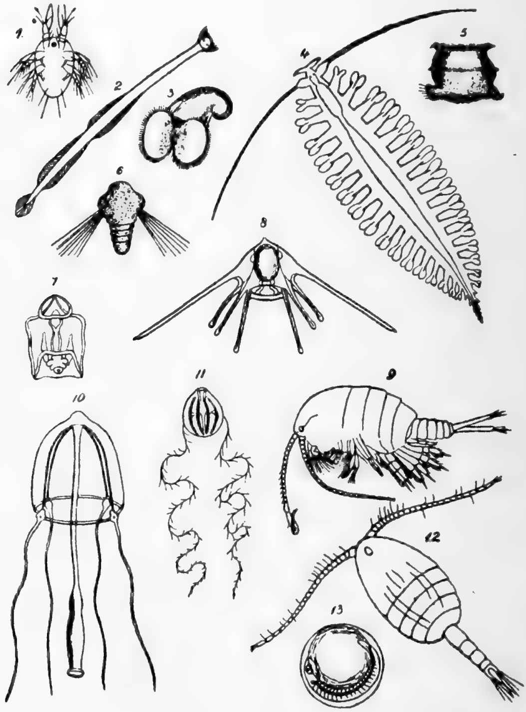


FIG. 25. "Plankton," caught in the surface net.

1 *Nauplius.* 2 *Sagitta.* 3 *larval Mollusc.* 4 *Tomopteris.* 5 *larval Polyzoon.* 6 *larval Polychaete.* 7 *larval Star-fish.* 8 *Ophiuroid "Pluteus."* 9 *Copepod.* 10 *Medusoid.* 11 *Cydippe.* 12 *Copepod.* 13 *Pelagic fish egg.*

We reproduce here a few of the figures from the Guide (see figs. 22, 23, 24 and 25) as examples of the illustrations. Figure 22 shows five Port Erin Echinodermata, viz., two starfishes, a brittle-star, a sea-urchin and a sea-cucumber, all of which may usually be seen in our aquaria.

Figure 23 represents small pieces of three common colonies of Hydroid Zoophytes, number 3 being natural size and numbers 1 and 2 showing expanded living zooids as seen enlarged under the microscope. Figure 24 gives a series of common Molluscs, including Bivalves, Univalves and Cuttlefishes. Finally, fig. 25 is an assemblage of "Plankton," the delicate and for the most part minute forms of life found floating in the surface waters of the sea, and which are collected by means of a fine silk tow-net. Amongst them occur (No. 13) the eggs and larvæ of many edible fishes, and also representatives of the Copepoda (9 and 12), small crustaceans which are of great economic importance as the food of fishes and other useful animals.

L.M.B.C. Memoirs.

Since the date of the last Annual Report the Committee have issued two Memoirs—

No. VIII. Pleuronectes, the Plaice, by Mr. F. J. Cole and Mr. James Johnstone; and

No. IX. Chondrus, a Red Sea-Weed, by Dr. O. V. Darbishire.

"Pleuronectes" is by far the largest and most elaborate Memoir we have yet published, and the Committee have to thank the Publication Committee of Victoria University for a grant-in-aid, of £35, to meet part of the expense of the preparation of the eleven beautiful plates showing the skull, brain, nerves, sense-organs and other details in the structure of the Plaice. "Chondrus" is our second botanical Memoir, the first being the green sea-weed "Codium," by Professor Harvey Gibson and Miss Helen Auld. We hope others will follow. Botanists require Biological Stations no less than Zoologists, and memoirs are still wanting on many marine plant types.

The next Memoir to be issued will probably be *Patella*—the Limpet—by Professor Ainsworth Davis and Mr. H. J. Fleure, the manuscript of which is now in the Editor's hands. Others upon *Arenicola*, the Fisherman's lug-worm, by Dr. J. H. Ashworth, and upon the Oyster, the Ostracod and *Antedon* are nearly ready. Mr. Cole, the senior author of "Pleuronectes," has made considerable progress with his Memoir on *Myxine*, the Hag-fish, and is preparing a series of very beautiful plates, towards the expense of lithographing which the Committee have to thank Mrs. Holt for a kind donation of £50, while Sir John Brunner has promised a similar amount to our Treasurer to complete the sum necessary. The list of the Memoirs published and in contemplation is now as follows:—

Memoir I. ASCIDIA, W. A. Herdman, 60 pp., 5 Pls., 2s.
,, II. CARDIUM, J. Johnstone, 92 pp., 7 Pls., 2s. 6d.
,, III. ECHINUS, H. C. Chadwick, 36 pp., 5 Pls., 2s.
,, IV. CODIUM, R. J. H. Gibson and Helen Auld, 26 pp., 3 Pls., 1s. 6d.
,, V. ALCYONIUM, S. J. Hickson, 30 pp., 3 Pls., 1s. 6d.
,, VI. LEPEOPHTHEIRUS AND LERNÆA, Andrew Scott, 62 pp., 5 Pls., 2s.
,, VII. LINEUS, R. C. Punnett, 40 pp., 4 Pls., 2s.
,, VIII. PLAICE, F. J. Cole and J. Johnstone, 260 pp., 11 Pls., 7s.
,, IX. CHONDRUS, O. V. Darbishire, 50 pp., 7 Pls., 2s. 6d.
,, X. PATELLA, J. R. A. Davis and H. J. Fleure, 84 pp., 4 Pls.
ARENICOLA, J. H. Ashworth.
BUGULA, Laura R. Thornely.
OYSTER, W. A. Herdman and J. T. Jenkins.

Ostracod (Cythere), Andrew Scott.
Myxine, F. J. Cole.
Antedon, H. C. Chadwick.
Buccinum, W. B. Randles.
Dendronotus, J. A. Clubb.
Peridinians, G. Murray and F. G. Whitting.
Zostera, R. J. Harvey Gibson.
Himanthalia, C. E. Jones.
Diatoms, F. E. Weiss.
Fucus, J. B. Farmer.
Botrylloides, W. A. Herdman.
Cuttle-Fish (Eledone), W. E. Hoyle.
Calanus, I. C. Thompson.
Actinia, J. A. Clubb.
Gammarus, M. Cussans.
Hydroid, E. T. Browne.
Calcareous Sponge, R. Hanitsch.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Sagitta* (by Mr. Cole), a Cestode (by Mr. Shipley), a Turbellarian (by Mr. Laidlaw), *Carcinus*, an Isopod and a Pycnogonid.

We append to this Report:—

A—The Curator's Report to the Committee.
B—Notes on the Fisheries of Port Erin.
C—Announcement of Easter Class for School Teachers.
D—The Constitution of the L.M.B.C. and the Port Erin Laboratory Regulations.
E—The Hon. Treasurer's Statement (which will be found at p. 76), with the usual List of Subscriptions and Balance Sheet.

Appendix A.

CURATOR'S REPORT TO THE COMMITTEE.

My time during the past year has been largely devoted to work in connection with the erection of the new building. The preparation of working drawings for the guidance of the workmen engaged in the erection of the laboratory workrooms, aquarium and hatchery tanks and other structural details occupied me at frequent intervals until the end of 1901. My thanks are due to Mr. James Hornell, of Jersey, and Mr. A. Scott, of the Piel Laboratory, for much valuable advice and assistance in the preparation of the drawings.

Early in the present year I carefully examined, cleaned and re-labelled the stock of preserved specimens, and they are now exhibited, with a number of recent additions, on the museum gallery of the new aquarium.

The interest in the work of the Station aroused in the minds of the local fishermen by the erection of the new building has resulted in the presentation of specimens of several of the less common fishes to our collection, and the addition of three names to our strictly local list of fishes. A specimen of Yarrell's Blenny, *Carelophus ascanii*, caught in a crab-pot, was brought in on March 22nd, and several others were found by myself and my assistant (T. N. Cregeen) while shore collecting on May 7th and 8th. On the latter date I found a full-grown specimen of the "Gattorugine," *Blennius gattorugine*, which lived for some weeks in a tank in the old aquarium. On June 6th a Tommy-Noddy, *Raniceps raninus*, caught on a line, was brought in, and a fortnight later a Muller's Top-knot, *Zeugopterus punctatus* was submitted to me by a fisherman for identification.

Mr. W. Watterson was again good enough to keep a record of the long-line fishing carried on by the Port Erin fishermen during the winter of 1901-2. This, together with a report on the local fisheries, prepared by my assistant, is appended (p. 53.)

With a view of ascertaining the minimum size at which the common lobster begins to spawn in this district, I determined at the beginning of the year to measure as many females "in berry" as possible, and to note the condition of the eggs. Measurements were made frequently until the middle of March, when the lobster fishery is discontinued to some extent, and my thanks are due to Mr. H. Cregeen, one of the principal lobster fishermen, for permission to measure the lobsters caught in his pots. Two of the specimens measured $8\frac{3}{4}$ inches from the tip of the rostrum to the end of the telson, but nearly half the total number were from 9 to 10 inches in length. The eggs were in all cases small and dark blue-black in colour, and appeared to be newly extruded.

On account of the large demands made upon my time by the erection and equipment of the new Station, I have not been able to pay much attention to faunistic work. Tow-netting and shore collecting have been carried on whenever possible, but with the exception of the fishes already noted, no specimens of special interest have come under my notice.

The Easter vacation party was again most successful. Favoured by plenty of genial sunshine and light winds, shore collecting and tow-netting excursions were engaged in almost daily by every member of the party; the caves in the vicinity of the Sugar-loaf Rock were visited, and much valuable material was collected and preserved for future study.

At the beginning of July the new building was so far complete as to allow of the removal of the instruments, books, re-agents, tanks, &c., from the old Station. This was done during the first week, and by the end of the second week all the effects were safely stored in the places assigned to them in the new laboratory. I then undertook the cementing of the plate-glass fronts in the nine large wall tanks in the aquarium. This occupied me until the beginning of August, by which time the contractors had nearly completed their work and withdrawn their men. I next completed the equipment of the laboratory, in anticipation of the arrival of students.

Two of the aquarium tanks were filled with water for the first time on August 18th, and all the tanks were completely filled by the 26th, without the occurrence of any appreciable leakage. On September 6th my assistant caught and placed in several of the tanks the first fishes, and from that time to the present he has devoted much time and enthusiasm to the capture of specimens of many of the local fishes. Of these, some few were more or less injured, and did not long survive capture, but the great majority were placed in the tanks in perfect health, and without exception are now doing well. A few of the local fishermen have rendered valuable assistance in stocking the tanks. At the present moment we have specimens of sea-bream, red gurnard, grey gurnard, angler, dragonet, wrasse, cod, haddock, whiting-pout, coal fish, pollock, whiting, turbot, plaice, dab, sole, conger, lesser spotted dog-fish and skate. Amongst the more familiar Invertebrates to be seen in the tanks may be mentioned the common lobster, spiny lobster, edible crab, cuttlefish and some sea-anemones.

Over 600 visitors have already paid for admission to the aquarium.

Appendix B.

NOTES ON THE FISHERIES OF PORT ERIN.

By Mr. T. N. Cregeen.

The Cod fishery proper begins in November and ends in March. The number of lines in use at the present time is about 22. The average length of each line is 750 fathoms, and hooks are attached, $2\frac{1}{2}$ fathoms apart, along the entire length. The lines are shot, tightly stretched and weighted at both ends, from one to six miles from the land, their position being indicated by skin floats attached to the weighted ends. They are sometimes left for a few hours only—at other times all night. The bait used is the whelk, *Buccinum undatum*, of which large numbers are caught in "pots" specially set for them.

The Lobster fishery begins in November, but about 40 pots and cages only are in use until January, when the number is increased to about 100. The pots and cages are baited with fresh fish, and are laid amongst the rocks all along the coast. They are hauled on an average every second day, and the average catch of lobsters per score pots is 10. A few crabs also are caught in them. The lobster fishery is carried on all through the summer until September, but after May about 30 pots only are in use.

The Crab fishery begins in February, the number of pots in use being about 140. These are baited with all kinds of stale or salt fish, are set close to the rocks all along the coast, and are hauled about three times per week. The average catch of crabs per 25 pots is about six dozen. This fishery is carried on until September, but as in the case of the lobster fishery, the number of pots in use during the summer months is much reduced.

What is locally known as the Fluke and Codling fishery begins in June, and is carried on with "small long lines." These are 450 fathoms long, the distance between the hooks being 1½ fathoms. About four of such lines are in use until September, when the number is increased to ten. The lines, baited with worms (*Nereis* and *Nephthys* are the most effective), limpets, hermit crabs and whelks, are shot in the bay and close in-shore along the neighbouring coast, and in addition to plaice and cod, there are also caught wrasse, haddock and gurnard.

The Pollack-Whiting, or "Callagh," fishery is carried on from January to October. "Swim" lines, about 20 fathoms long and carrying one hook are used, the bait being worms (*Nereis* and *Nephthys*), skin of butter-fish, and patent bait. The lines are "trawled" from a boat rowed slowly a few yards from the rocky coast. The Coal Fish, or "Blochan," is caught in the same way.

The Conger, Ling and Skate fishery is carried on principally in July, August and September. The lines used are the same as for cod, but the bait used is herring and mackerel. This fishery is conducted from one to four miles from the land.

Ground or Bottom fishing is largely pursued during the summer months, chiefly for the amusement of holiday visitors. Weighted hand-lines, carrying one or two hooks baited with herring, mackerel and crabs, are used, and the fish caught are sea-carp, gurnard, whiting, conger, ling, cod, haddock, skate, ray and dog-fish.

Mackerel fishing begins in July, and is carried on until September, when the mackerel leave the coast. The lines used are about 20 fathoms long, and carry one or two hooks baited with a small strip of the white skin of the mackerel, or should this not be obtainable, a bright patent bait. The flower of the fuchsia has also been used with success. The lines are weighted, and "trawled" behind sailing or rowing boats.

The Herring fishery is pursued by a small number of boats from May to October. The "drift" nets used are, when barked and ready for use, about 35 fathoms long and from 6 to 8 fathoms wide or deep. From 18 to 20 nets, fastened together end to end, are used by each boat. They are shot between sunset and sunrise, one edge being kept about three fathoms below the surface by means of floats, while the other is weighted with small ropes, called "underbacks." When shot the nets and boat are allowed to drift with the tide.

What is locally called trawl-net fishing is engaged in at the latter end of September and October. The trawl net is 50 fathoms long and 3 fathoms wide. The size of the mesh varies, and in at least one net causes the destruction of numbers of immature fish. A rope about 100 fathoms long is attached to either end of the net, which is shot from a boat rowed close to the shore; the rope at one end is left on the beach, the one at the other is landed by the men in the boat, when the whole length of the net has been shot. The two ends are now hauled ashore, the two parties of men closing upon each other in order to drive the fish enclosed towards the centre of the net. The fish caught in this way are coal-fish, plaice, mullet, and occasionally salmon. The net is invariably used after dark, and at early flood tide.

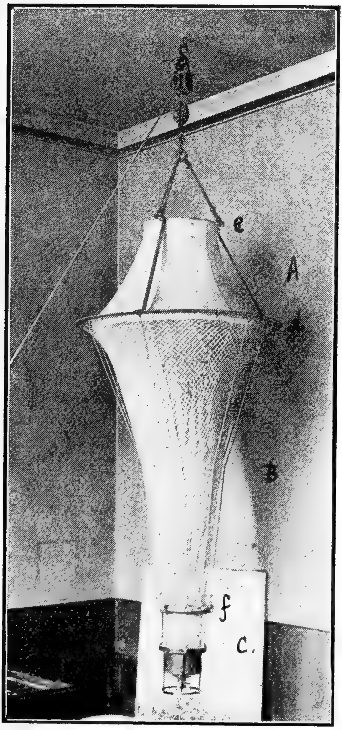
Three or four trammel nets, like those used in the estuary of the Dee, are used in the bay and its immediate neighbourhood during the summer months, but the number of fish caught by their means, such as plaice, small cod and gurnard, is not large.

Mr. Watterson's record of the long line fishing during last winter is as follows:—

Date.		Number of Lines shot.	Cod.	Fish Caught. Haddock.	Conger.	Skate.
January	14	2	30	—	—	—
	16	2	21	—	—	—
	18	2	29	—	—	—
	23	6	83	—	—	—
	24	4	31	—	—	—
	29	1	10	—	—	—
	30	13	93	5	4	3
February	1	18	210	5	1	5
	3	3	31	2	3	—
	4	14	177	—	5	1
	5	9	21	2	7	3
	6	6	25	4	9	70
	7	15	82	3	11	50
	8	1	—	—	—	—
	10	16	48	2	11	7
	11	5	13	—	8	9
	12	14	94	7	5	5
	13	6	19	4	3	2
	14	17	108	5	5	7
	15	6	35	3	2	9
	18	20	160	3	9	11
	19	2	25	—	1	—
	20	22	121	11	6	10
	21	6	42	—	—	–
	24	15	110	3	4	6
	25	22	170	2	6	13
	27	20	126	21	—	7
March	1	6	40	—	—	—
	4	6	80	5	—	4
	5	8	120	7	2	4
	6	15	180	5	—	1
	7	7	90	4	1	4
	8	17	130	4	3	30
	11	17	140	14	—	2
	13	10	80	10	—	3
	15	13	120	20	4	9
	18	4	20	2	1	—
	21	6	50	12	1	5
	22	6	30	—	2	—
	24	5	37	13	1	5
	25	2	9	—	—	8
	27	11	90	10	2	16

The totals are as follows:—

Number of days fishing	...	42	
,, lines shot	...	400	
,, baited hooks	...	120,000	
,, Cod caught	...	... ...	3,130
,, Haddock caught		... ...	188
,, Conger ,,		... ...	118
,, Skate ,,		... ...	309
Total number of fish caught		... ...	3,745



Hensen's Large Vertical Net for collecting Plankton.

Appendix C.

EASTER CLASS FOR SCHOOL TEACHERS.

This subject has been referred to in former Reports, and now that the new buildings afford the necessary accommodation, the L.M.B.C. has, in consultation with the Nature-Study Association of Teachers in Liverpool, drawn up the following circular:—

Special Class in Marine Biology, or Nature-Study, for School Teachers, to be held at Port Erin, Isle of Man, during the Easter Holidays, 1903.

The Liverpool Marine Biology Committee, in response to a demand, is willing to make arrangements for a special class in Elementary Marine Biology, to illustrate the principles of nature-study, and to be held at the Port Erin Biological Station during the Easter holidays, 1903. The Station is a new building situated on the sea-shore, and is admirably adapted in every respect for classes of this description.

A large laboratory on the first floor, provided with fourteen windows, will be set aside wholly for this purpose during the time of the class. Each member of the class will occupy a table or workplace opposite a window, and will be provided with the necessary animals (or when possible, and as is much better, will be shown how to collect them himself), salt and fresh water, and all materials and apparatus necessary for the work.

The course is necessarily restricted to the Easter holidays, and will therefore extend from Saturday, April 10th to Saturday, April 17th. If, however, any are able and willing to stay longer, further arrangements can be made at the time.

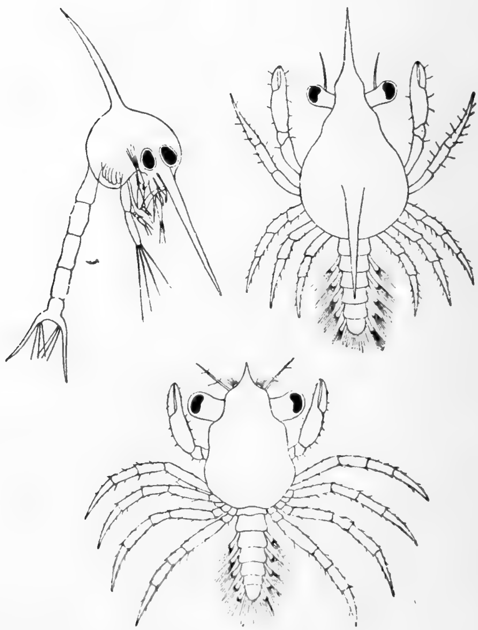
The class will be limited to twelve students, each of whom will pay 6s. to the L.M.B.C. for the use of the laboratory, and in addition a tuition fee of 10s. These fees should be remitted to Mr. Cole before the opening of the class. No definite time table of the class work can be drawn up, and the time and nature of the work will depend largely on the tides, weather, &c. Speaking generally, however, the class will spend the morning in the laboratory, examining animals in the living condition, and making simple biological experiments thereon. In the afternoons collecting excursions, with the object of studying the animals in their natural surroundings, and also expeditions for collecting and dredging from boats, will be organised and led by members of the L.M.B.C. At other times short addresses and demonstrations in the aquarium and museum will be given by Prof. Herdman, Mr. Chadwick and others. No previous knowledge will be supposed. The class work will be directed by Mr. F. J. Cole, Lecturer and Demonstrator of Zoology, University College, Liverpool.

The Treasurer of the L.M.B.C. wishes to point out that, as the charge is at about one half the usual rate for accommodation, it must be regarded as a special charge for this occasion, and for a class of not less than twelve, and will not apply to single students or at other times.

Each member of the class must be provided with a large drawing-book, pencils and india-rubber and a duster or small towel. All further apparatus, as follows—enamelled dissecting dishes, with wax at the bottom, several crystallising dishes and watch glasses, microscope slides and cover-glasses, dipping tubes, some simple dissecting instruments, a powerful hand lens, occasional microscopes, and collecting jars, will be lent, without charge, by the L.M.B.C., to the students.

If the student wishes to take away any animals for examination at home, bottles, tubes and methylated spirit and other preservatives can be bought from the Station stock on application to the Curator.

Any further details may be arranged, and questions asked, before the class commences, by correspondence with Mr. F. J. Cole, University College, Liverpool.



Stages in the Life-History of the Shore Crab.

Appendix D.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1902).

His Excellency Lord Raglan, Governor of the Isle of Man.

Mr. R. D. Darbishire, B.A., F.G.S., Manchester.

Prof. R. J. Harvey Gibson, M.A., F.L.S., 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. W. E. Hoyle, M.A., Owens College, Manchester.

Mr. P. M. C. Kermode, Secy., Nat. Hist. Soc., Ramsey, Isle-of-Man.

Mr. A. Leicester, Liverpool.

Sir James Poole, J.P., Liverpool.

Dr. Isaac Roberts, F.R.S., formerly of Liverpool.

Mr. I. C. Thompson, F.L.S., 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.

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.

Laboratory Regulations.

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

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 Colleges 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.

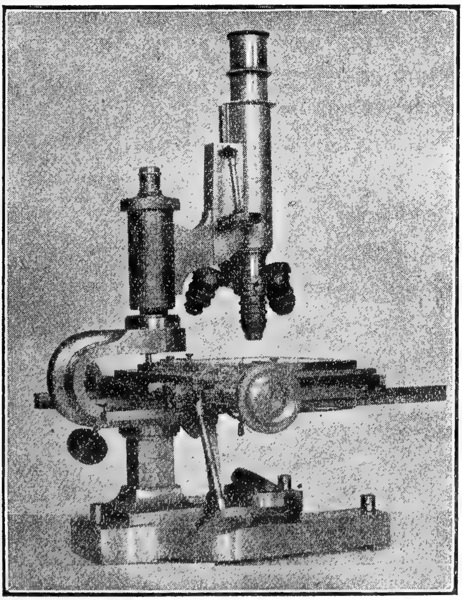
VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes, reagents, and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

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

Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

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

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer, Mr. I. C. Thompson, F.L.S., 53, Croxteth Road, Liverpool. 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 College, Liverpool.



Plankton Microscope, as used at Kiel, with large Mechanical Stage.

Appendix E.

HON. TREASURER'S STATEMENT.

As usual the list of subscribers and the balance sheet are appended, the latter again showing a small adverse balance.

The report of the Director clearly indicates the necessity there is for kindly increased support by subscriptions and donations now that the commodious new Biological Station is in occupation.

As stated in the Report, further valued donations have been made to the fund for publishing Biological Memoirs. The accounts of this fund are kept separately, and do not therefore appear in the annexed balance sheet.

The Library for the use of students and workers at the Port Erin Station is urgently in want of many standard Biological works. The Treasurer gratefully acknowledges the sum of £5 received from Mrs. Herdman towards this object. Further donations towards the library will be most welcome.

The Treasurer will gladly receive the names of new subscribers, with the view of continuing the publication of important Memoirs, and of aiding to defray the increased working expenses of the Biological Station, and of thus further adding very materially to the already excellent work achieved under the auspices of the L.M.B.C. since its foundation, seventeen years ago.

Isaac C. Thompson, Hon. Treasurer,

53, Croxteth Road, Liverpool.

SUBSCRIPTIONS AND DONATIONS.

	Subscriptions. £	s.	d.
Ayre, John W., Ripponden, Halifax	1	1	0
Bateson, Alfred, Styal, Manchester	1	1	0
Beaumont, W. J., Citadel Hill, Plymouth ...	1	1	0
Bickersteth, Dr., 2, Rodney-street...	2	2	0
Brown, Prof. J. Campbell, Univ. Coll.	1	1	0
Browne, Edward T., B.A., 141, Uxbridge-road, Shepherd's Bush, London	1	1	0
Brunner, Sir J. T., Bart., M.P., L'pool	5	0	0
Boyce, Prof., University College	1	1	0
Clague, Dr., Castletown, Isle of Man	1	1	0
Clubb, J. A., Public Museums, Liverpool... ...	0	10	6
Crellin, John C., J.P., Andreas, I. of Man... ...	0	10	6
Gair, H. W., Smithdown-rd., Wavertree ...	2	2	0
Gamble, Sir David, C.B., St. Helens	2	0	0
Gamble, F. W., Owens College, Manchester... ...	1	1	0
Gaskell, Holbrook, J.P., Woolton Wood... ...	1	1	0
Halls, W. J., 35, Lord-street	1	1	0
Hanitsch, Dr., Museum, Singapore	1	1	0
Herdman, Prof., University College	2	2	0
Hewitt, David B., J.P., Northwich	1	1	0
Holland, Walter, Mossley Hill-road	2	2	0
Holt, Alfred, Crofton, Aigburth	2	2	0
Holt, Mrs., Sudley, Mossley Hill	2	2	0
Holt, R. D., 54, Ullet-road, Liverpool	2	0	0
Hoyle, W. E., Museum, Owens College	1	1	0
Isle of Man Natural History Society	1	1	0
Jarmay, Gustav, Hartford	1	1	0
Jones, C.W., J.P., Allerton Beeches	1	0	0
Kermode, P. M. C., Hill-side, Ramsey	1	1	0
Lea, Rev. T. Simcox, St. Ambrose Vicarage, Widnes	1	1	0
Forward	£41	10	0

	Subscriptions. £	s.	d.
Forward	41	10	0
Leicester, Alfred, Scott Dale, New Ferry... ...	1	1	0
Lewis, Dr. W. B., West Riding Asylum, Wakefield	1	0	0
Manchester Microscopical Society...	1	1	0
Meade-King, R. R., 4 Oldhall-street	0	10	0
Melly, W. R., 90, Chatham-street	1	1	0
Monks, F. W., Brooklands, Warrington	2	2	0
Muspratt, E. K., Seaforth Hall	5	0	0
Newton, John, M.R.C.S., Prince's Gate	0	10	6
Okell, Robert, B.A., Sutton, Douglas	1	1	0
Paterson, Prof., University College	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... .	1	1	0
Rathbone, Miss May, Backwood, Neston... ...	1	1	0
Rathbone, W., the late, Greenbank	2	2	0
Roberts, Dr. Isaac, F.R.S., Crowborough... ...	2	2	0
Simpson, J. Hope, Aigburth-drive	1	1	0
Smith, A. T., 35, Castle-street	1	1	0
Talbot, Rev. T. U., Douglas, Isle of Man... ...	1	1	0
Thompson, Isaac C., 53, Croxteth-road	2	2	0
Thornely, The Misses, Aigburth-Hall-rd.... ...	1	1	0
Timmis, T. Sutton, Cleveley, Allerton	2	2	0
Toll, J. M., Kirby Park, Kirby	1	1	0
Walker, A. O., Ulcombe Place, Maidstone... ...	3	3	0
Walker, Horace, South Lodge, Princes-pk.... ...	1	1	0
Watson, A. T., Tapton-crescent, Sheffield... ...	1	1	0
Weiss, Prof. F. E., Owens College, Manchester	1	1	0
Wiglesworth, Dr., Rainhill...	1	1	0
Yates, Harry, 75, Shude-hill, Manchester... ...	1	1	0
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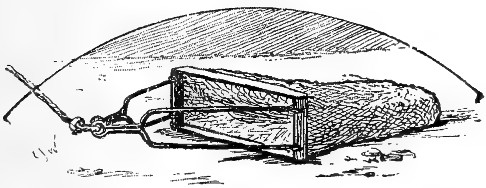


The Naturalists' Dredge.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr. IN ACCOUNT WITH ISAAC C. THOMPSON, HON. TREASURER. **Cr.**

1902.	£	s.	d.
To Balance due Treasurer, Dec. 31st, 1901	2	17	9
,, Printing Reports and "Aquarium Guide"	20	0	1
,, Printing and Stationery	0	14	0
,, Expenses of Dredging Expeditions	24	13	1
,, Boat Hire and Boat Repairs	1	3	3
,, Books and Apparatus at Port Erin Biological Station	13	17	4
,, Lighting and Heating	0	18	8
,, Postage, Carriage, &c.	5	5	0
,, Salary, Curator	77	18	4
,, ,, Assistant	11	0	0
,, Rent of Port Erin Biological Station	2	6	10
,, Sundries	2	9	9
	£163	4	1

1902.	£	s.	d.
By Subscriptions and Donations received	81	7	0
,, Amount received from Colleges, &c., for hire of "Work Tables"	30	0	0
,, Dividend, British Workman's Public House Co., Ltd., Shares	8	13	3
,, Sale of Nat. Hist. Specimens	2	12	11
,, Sale of Reports and Volumes of Fauna	0	7	6
,, Interest on British Association (1896) Fund	37	11	8
,, Bank Interest	0	6	0
,, Admissions to Aquarium	1	1	6
,, Balance due Treasurer, Dec. 31st, 1902	1	4	3
	£163	4	1

Endowment Invested Fund:—
British Workman's Public House Co.'s shares £173 1 0

ISAAC C. THOMPSON,
HON. TREASURER.

LIVERPOOL, *December 31st, 1902.*

Audited and found correct,
A. T. SMITH.

CLUNIO BICOLOR, KIEFF;

A MARINE CHIRONOMID NEW TO THE FAUNA OF GREAT BRITAIN.

By A. D. IMMS,

Zoological Laboratory, University of Birmingham.

During the middle of August, 1902,* I came across a number of small dipterous insects skimming over the surface of the rock pools on the shores about Port Erin, Isle of Man. Upon one calm sunny day they were about in considerable numbers, and I was able to secure several of them. On the following day I observed a few in a similar situation at Fleshwick Bay, a locality a few miles north of Port Erin. When I first examined these specimens, I thought them to be the males of *Clunio marinus*, Hal., but, after a subsequent careful reconsideration, I detected differences, and found that the species to which they belong is *Clunio bicolor*, Kieff. I am indebted to the kindness of M. l'Abbe J. J. Kieffer for corroborating my identification as *C. bicolor*, and to M. Henri Gadeau de Kerville who sent me some spirit specimens of this insect, last year, from the coasts of France. During the short time I was able to devote to searching for this insect, I only met with one female

* While occupying the University of Birmingham Table at the Marine Biological Laboratory, Port Erin.

example. The male appears to be only on the wing during fine weather, and, owing to its fragility, even but a slight wind seems detrimental to it. Flying in company with the *Clunio* were both sexes of a species of *Chironomus*, the female of which it resembles very closely both in size and colour; and, at first sight, it was not easy to discriminate between the two species when they were on the wing. The *Clunio* flies but short distances at a time, generally about two feet, settling but for a moment between each effort. The wings during the whole time are incessantly in vibration. It is only seen at low water, and lives for a very short time, probably not surviving until a second ebb tide. I have not seen it ascend into the air, or do otherwise than merely skim over the water and rocks within a few inches of the surface. The single female which I met with was observed resting upon the surface film of the water; and she is likewise very short lived. The genus *Clunio* was erected by Haliday in 1855 for the males of a single species (*C. marinus*) which he found on the shores of Kerry below high-water mark. He diagnosed the genus as follows:—

"Proboscis obsoleta. Antennæ 11-articulatæ, articulis 3-tio et ultimo elongatis. Alæ alutaceæ, venis longitudinalibus furcatis binis, transversis nullis. Tarsi postici articulo tertio subelongato."§

Rather than present any detailed description of *Clunio bicolor*, I append the careful description of *C. marinus* given by that inimitable entomologist, and then point out the differences between the two species.

Haliday's description is as follows:—

"Long $\frac{4}{5}$, Exp. $\frac{9}{5}$ lines. Head rounded, dusky ferruginous, concealed under the projecting front of thorax,

§ Unfortunately published in a journal now long extinct.

the mouth inflected to the prosternum. Eyes round, composed of few facets, with some hairs interspersed, approximate on the face. Antennæ inserted near the mouth, shorter than the thorax, 11-jointed, whitish, the third joint elongated, the others short and more dusky, the last again elongated and thickened, elliptical. Proboscis obsolete, only the lower margin of the head scalloped, the rounded lateral lobes a little hairy at the tip, perhaps representing palpi, and the intermediate divided lobe the labium. Thorax dusky ferruginous, with the scutellum and pleuræ yellowish; oblong, a little compressed; the mesonotum tripartite by two impressed parallel longitudinal lines, and elevated line down the middle, ending in the depression before the scutellum; this convex semicircular; metathorax very short; mesonotum gibbous backwards. Legs rather short, compressed, dingy white, pubescent; the hind tibiæ at the tip, and the hind tarsi ciliated. Fore coxa twisted, the trochanter toothed, and the base of the femur curved. Tibiæ blackish at the very base, armed at the tip with a minute black pointed spur. Anterior tarsi with the first joint linear, the following ones short suborbiculate, the last ovate; hind tarsus with the first and third linear, the second oblong, half as long as the third, the fourth short suborbiculate. Ungues dusky; empodium apparently dilated more than the onychia. Posterior coxæ extending backwards under the base of the abdomen. Wings oblong, with the axillary sinus semicircular, and the anal angle strong; the membrane adiaphanous, dingy whitish, microscopically stippled, glabrous, only the margin finely pubescent. The veins faint, the radial ending a little before the middle of the costa, the præbrachial is forked opposite the end of the first, the posterior branch running to the tip, the anterior ending not far before it; podobrachial runs to the posterior margin, becoming forked beyond the middle, with the posterior branch (subanal) curved, and another very faint simple vein (anal) accompanies the course of this. Halteres whitish. Abdomen scarcely as long as the thorax, gradually widened behind, of 7 segments, dusky, with a hoary bloom, and a pearly gloss on the posterior segments Hypopygium as long as the abdomen, and thicker, fusco-ferruginous, with yellowish silky down, and composed of an oblong plate below, rounded at the tip, and a pair of massive compressed lateral arms, with a double ridge beneath, and rounded at the tip, where they are articulated to a smaller compressed piece, dilated at the tip, and truncated (mallet-shaped)."

The differences between the two species do not warrant a minute description, and may, perhaps, be best shown in synoptical form.

Antennary shaft bicolorous, the first and last joints white, the eight intervening ones brown; thorax brown, with a long median longitudinal band of a brighter colour and traversed down its centre by a brownish line; scutellum whitish green with a brown transverse marking; wings with a faint vein between the "anal" and "podobrachial" veins; abdomen green, slightly longer than the claspers—*C. bicolor*.

Antennary shaft whitish throughout; wings with no vein between the "anal" and "podobrachial" veins; abdomen brown like the thorax and claspers, shorter than the claspers—*C. marinus*.

The male of *Clunio bicolor* was discovered by Gadeau de Kerville in the Bay of Saint Martin in 1899; in 1900 some specimens were obtained by Chevrel at Saint Briac (Ille et Vilaine). It has not been recorded from any other localities, and through its occurrence at Port Erin I am able to add it as a species new to the British Dipterous fauna.

The female very closely resembles that of *C. marinus*, the distinctions are merely those of colour; the female of the latter species has not been described minutely, and, hence, I am unable to point out any differences between it and my spirit specimen of *C. bicolor*. It has not previously been met with, and I can fully endorse the recent suggestion of Gadeau de Kerville who remarks, " La femelle est jus qu'alors inconnue. Il y a tout lieu de supposer qu'elle est apteré et vermiforme, comme celle du *Clunio marinus*." The larva and pupa are, as yet, unknown.

The text-figures show both sexes of the fly, with an enlarged head of the male.

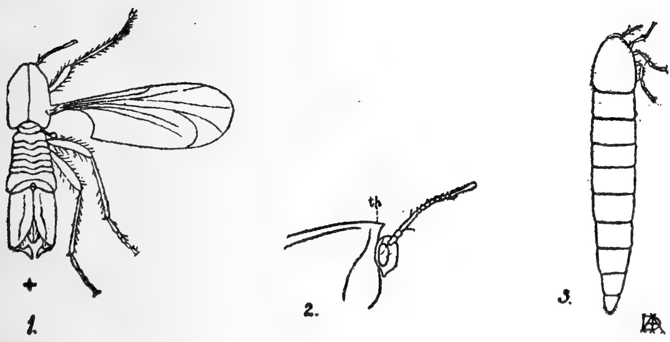


FIG. 1. Male of *Clunio bicolor*. FIG. 2. Lateral view of head of same, shewing projecting anterior margin of thorax. FIG. 3. Female fly. The natural size is indicated by the lines alongside figure 1.

LITERATURE.

1855. A. H. Haliday. Nat. Hist. Rev., vol. ii., Proc. p. 54, pl. ii.

1900. H. Gadeau de Kerville. Bull. Soc. Amis Sci. Nat. Rouen, proc.-verb. 8th Nov. (with Kieffer's description of *Clunio bicolor*).

1901. ———————. Ib. pp. 194-206.

1902. A. D. Imms. Entom., vol. xxxv., pp. 157-158. (With a bibliography of the genus).

REPORT on the INVESTIGATIONS carried on during 1902 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at University College, Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. ANDREW SCOTT, A.L.S., Resident Fisheries Assistant at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries Assistant at the Liverpool Laboratory.

(With tables, charts and figures in the text.)

CONTENTS.

INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

THE work of the past year has been chiefly:—

(1) The hatching operations and other similar work carried out at Piel by Mr. Andrew Scott;

(2) Laboratory investigations by Mr. Johnstone at Liverpool;

(3) Analysis and discussion of our fishery statistics;

(4) The work of the circulating Fisheries Exhibition;

(5) Practical Laboratory Classes for Fishermen; and

(6) I may add my own work in connection with the Report of the Ichthyological Research Committee, which has a considerable bearing upon our local investigations.

Some of these matters which can be treated shortly I shall remark upon here; the others will be discussed more fully in the separate sections that follow.

This year we have no appendix on a marine animal of economic value, like the detailed work on the Plaice, by Mr. Cole and Mr. Johnstone, which adorned the Report last year; but we have several such in progress—on the Oyster, on the Fisherman's Lug-worm, on the Edible Whelk, and others—which we hope may appear in future Reports.

The Piel Hatchery.

Mr. Scott's account of the Sea-Fish Hatching work at Piel will be found in the next section of the Report. During this year we have added Plaice to the Flounders dealt with previously. The result has been, because of the larger size both of the adult fish and of the ova, and therefore the impossibility of accommodating so many spawners in our very limited space, a diminution in the total number of ova dealt with and of fry set free. But still over a million of young Plaice and over ten millions of young Flounders have been set free during the season in our district. Our greatest want in this connection is a large spawning pond, which could be used in part for the adult fish and in part for the rearing of the young. We are unable to do anything in that direction until this want is supplied. The pond at the Aberdeen Hatchery is, we understand, proving a success; and the new hatchery which has been erected by the Manx Government in connection with the Biological Station at Port Erin has a pond measuring nearly 100 by 50 feet, and from 3 to 10 feet in depth, which it is hoped will enable adult fish to be kept all the year round, and will also serve for the rearing of young both of fish and lobsters. It is not too much to say that no hatchery is complete without a spawning pond, and that the want of one at Piel seriously impedes Mr. Scott's operations. We are now preparing for the work of the coming season, and again we are indebted to the courtesy of the Fishery Board for Scotland for permission to trawl for large plaice in their closed waters of Luce Bay.

Mr. Scott also gives us an interesting account of the method of spawning of the Lobster, as observed by him in our Hatchery at Piel; and a discussion of some results that have been reported of the success attained by trawlers in fertilising fish eggs at sea.

Mr. Scott reports that the Laboratory at Piel has been occupied by several scientific workers during the year. In addition to our own Assistants, Mr. Scott and Mr. Johnstone, who were occupied both in research and also with practical classes for fishermen, we had, during the Easter vacation, Dr. H. Lyster Jameson, from the Municipal Technical College at Derby, who continued his investigations on the formation of pearls in marine mussels. Dr. Jameson has since published a paper on the subject in the Proceedings of the Zoological Society, which deals with the observations made at Piel and elsewhere. Mr. Joseph Pearson, B.Sc., and Mr. Walter Tattersall, B.Sc., two research students from University College, Liverpool, worked at general Marine Zoology during September. Amongst other Scientific or Technical visitors who have been at Piel during the year to inspect the laboratory and see the progress of our work were the following:—

Mr. C. E. Fryer, Inspector of Fisheries, Board of Trade.

Dr. H. Timbrell Bulstrode, Local Government Board.

Sir J. T. Hibbert, Chairman of the Lancashire County Council.

Mr. F. J. Ramsden, Furness Railway Company.

Dr. Snape, Director of Technical Instruction, Preston.

Mr. John Fell, Chairman, Sea-Fisheries Committee.

Mr. James Fletcher, Sea-Fisheries Committee.

Colonel Turner, Sea-Fisheries Committee.

Mr. J. P. Muspratt, County Offices, Preston.

Mr. R. A. Dawson, Preston.

Mr. J. Shepherd, B.Sc., University Tutorial College, London.

Rev. T. Fowler, Flookborough.

Professor Herdman, Liverpool.

Also the Chairman and Members of a number of the Lancashire local Technical Instruction Committees, the Barrow Field Naturalists' Club, and parties from Liverpool and Manchester.

Fisheries Exhibition.

The Travelling Fisheries Exhibition, which was sent to Piel in 1900, was lent to the Barrow Town Council from October, 1901, to April, 1902. It was then returned to Piel, where it is still exhibited.* In Barrow the Exhibition was shown in the Public Library, and the Town Council report to us that "The Exhibition Sub-Committee feel that the result of obtaining the Fisheries Exhibition for the use of the public has been a success, and has encouraged the hope that it is only the forerunner of the establishment of a permanent Museum in Barrow. The interest shown in the exhibition, particularly by the school children, leads the Committee to believe that it has undoubtedly been of educational value."

Classes for Fishermen.

Two practical Classes for Fishermen, on the same lines as those held in former years, and subsidised as before by the Technical Instruction Committee, were held at Piel

* Any other Museums or Public Institutions within the contributing counties desiring to have the Fisheries Exhibit on loan should apply for a copy of the conditions.

during the hatching season of 1902. The following are the dates and the names of the men who attended:—

(1) April 7th to April 18th—John Wright, Southport; Robert Wright, Southport; J. Bond, Banks; Richard Abram, Banks; Thomas Rimmer, St. Annes; Isaac Dobson, St. Annes; Peter Whiteside, Lytham; W. Croft, Fleetwood; J. Croft, Fleetwood; S. P. Colley, Fleetwood; Robert Blundell, Fleetwood; William Beesley, Morecambe; William Woodhouse, Morecambe; John Johnson, Morecambe; Edward Gardner, Morecambe.

(2) April 28th to May 9th—Henry Wright, Southport; Daniel Rigby, Southport; Richard Robinson, Southport; Robert Johnson, Southport; Alfred Threlfall, Fleetwood; R. W. Gardner, Sunderland Point; Joseph Bell, Morecambe; William Armistead, Morecambe; Robert Wilson, Morecambe; William Hartley, Bardsea; Thomas Dickinson, Bardsea; Robert Thompson, Baycliff; William Bulter, Flookborough; Richard Burrow, Flookborough; Robert Burrow, Flookborough.

The classes were conducted by Mr. J. Johnstone and Mr. A. Scott, and the course of instruction was practically the same as that given in the classes of previous years, with the addition that one afternoon was spent in showing a few simple chemical experiments of biological importance, demonstrating the composition of air and water, and the relation between these bodies and the respiration of marine animals.

The student-fishermen all took an intelligent interest in the work of the class. Many of them had brought note-books, in which they took records of the work done and copies of the various illustrations drawn on the black-board. These note-books were looked over by Mr. Johnstone before the classes broke up, and additional information was added, so as to render the notes more valuable for future reference. At the conclusion of each class the men expressed their indebtedness to the Technical Instruction Committee and to the Sea-Fisheries Committee for this arrangement by which they are enabled to come to Piel and receive practical instruction concerning the life and habits of the more important marine animals.

From the number of enquiries we have had for information as to the methods adopted in carrying on these classes, it is evident that the importance of practical instruction to fishermen on the nature, life histories and habits of the economic marine animals is being more appreciated each year. Other Fisheries Authorities are now taking up the work. The Eastern Sea-Fisheries Committee asked permission for some of their men to attend at Piel along with the Lancashire fishermen; and amongst the enquiries for particulars as to the methods of organisation was one on behalf of the Japanese Minister of Fisheries. We give at the end of this Report a more detailed statement which has been recently drawn up as to the Technical Fisheries Instruction provided under the auspices of our Committee.

Experiments with "Drifters."

It will be remembered that in several former reports (see especially those for 1895 and 1898) we dealt with the surface currents of our sea which might carry floating fish eggs and larvæ, as determined by the distribution of numbered "drift" bottles set free at times and localities duly noted, and containing post cards to be filled in and returned by the finder. As it had become desirable to ascertain where fish eggs produced in the deep water off Carnarvon and Cardigan Bays, the Welsh portion of our extended district, would be carried to, I arranged to set free a new series of drift bottles during my passage down the Channel last winter, on the way to Ceylon. Consequently during the first night after leaving Liverpool, from the N.W. Lightship onwards, Mr. Hornell and I set free 200 drift bottles, in batches of 10, thrown overboard every half hour or quarter hour, according to the locality, from 1.30 to 10.30 a.m. The experiment was remarkably successful; 118 out of the 200 bottles were subsequently found, and Mr. Johnstone has worked out the particulars of their probable journeys, and the evidence they give us as to the drift of small objects in that part of the Irish Sea. The experiment seems to prove, what was previously suspected, that the eggs of fish spawning off Carnarvon and Cardigan Bays will probably find their way into Lancashire waters, and by the time they have come to be post-larval will be in a position to recruit the populations of our coastal "nurseries."

Other Investigations.

One of our former students of fishery matters, Dr. J. Travis Jenkins, now Lecturer in Biology in the Hartley College, Southampton, contributes a paper to this Report upon the question of supposed "spring" and "autumn" races of the Herring. There are undoubtedly two main spawning seasons for the Herring in our seas, the one in spring and the other in autumn, and the German Naturalist, Professor F. Heincke, has contended that it is two distinct races of Herring that spawn at these two seasons.

Dr. Jenkins' discussion of the known facts, and his careful analysis and criticism of Heincke's figures and arguments, show that we have not yet sufficient evidence to enable us to separate the Herrings of our seas into a "spring" and an "autumn" race.

Mr. Johnstone gives a translation of Dr. Heincke's table for the identification of the floating fish eggs found in our seas, which will no doubt be found very useful in this English form.

Mr. Johnstone has devoted some time during the year to an examination of our trawling statistics collected on the steamer and otherwise, with the result that he is able to draw some conclusions of importance which are discussed in his article below. He also gives us a valuable contribution to that important subject, the comparability of hauls taken under closely similar conditions. This matter is fundamental for all arguments based upon observations and statistics which are only samples, and Mr. Johnstone's results show that we must be even more careful than had been supposed in the collection and comparison of such statistics, and in drawing any conclusions from them.

On my recommendation, an application to the Scientific Sub-Committee from the authorities of the Liverpool Free Public Museum to be allowed on occasions to use a small meshed (illegal) net in and about the mouth of the Mersey for the purpose of obtaining specimens for the Aquarium, was granted. The report from the Museum upon the result, which is required by the Committee on each such occasion, shows that along with the common animals usually caught in the locality, there were two rarer species, which have been obtained during the summer, viz., the Spotted Dragonet, *Callionymus maculatus*, and a Cirripede parasite of the hermit crab, named *Peltogaster paguri*. Both had been first found in our district some years ago by the Liverpool Marine Biology Committee. The *Peltogaster* had been recognised and labelled in the Zoology Museum of University College, but the *Callionymus* was not finally identified until seen both at the Public Museum and at the College Museum by the practised eye of Mr. Scott. This is only one of many cases of new records to our district that we owe to the skill and faunistic knowledge of Mr. Scott.

The important question of the pollution by sewage of our shore fisheries, and especially shell-fish beds, is once more exciting public attention. We have made contributions to the subject in several previous reports, and we now propose, in co-operation with Mr. Dawson and the bailiffs, to make a thorough examination of the shell-fish beds of our district, so that we may be in a position to advise the Committee or the Public Health Authorities upon any particular cases that may arise.

Report of the Ichthyological Research Committee.

My own chief contribution to the Report this year is a discussion of the International North Sea Investigation and of the Report of the Ichthyological Research Committee lately issued as a Government Blue Book. The international scheme is an interesting scientific investigation undertaken in conjunction with certain foreign nations for three years, and in regard to the practical utility of which, for British fisheries, opinion is much divided.

The Ichthyological Committee has produced a report which consists partly of a discussion of the problems that are most important at present to the British fishing industries, and of the manner in which these problems must be investigated, and partly of a comprehensive scheme for organising sea-fisheries research throughout the country. It is recommended that Government should constitute a "Fishery Council for England" consisting of representatives of (*a*) the Board of Trade, (*b*) the Local Sea-Fisheries Committees, and (*c*) the scientific men directing the work of certain marine laboratories. Each coast of England (East, South and West) is treated separately, and each, it is suggested, should have its own steamer for special investigations and its own marine laboratory, existing institutions being made use of whenever possible. If these recommendations of this Committee, on which were representatives of several Government departments, and of the Central Fisheries Authorities of England, Scotland and Ireland, as well as independent scientific men, are carried out in a liberal spirit by the Government, they will go far, I believe, to remedy the existing unsatisfactory state of affairs, and to bring about a national scheme of fisheries investigation centring in the Board of Trade, but representing all interests—official, trade and scientific—and conducing to the prosperity of an important industry.

W. A. HERDMAN.

University College, Liverpool,
January, 1903.

Sea Fish Hatching at Piel.

By Andrew Scott.

In the operations carried on during the fish hatching season of 1902, the eggs of both plaice and flounder were dealt with. The number of eggs incubated and fry set free, fall short of last year's figures. This reduction is due to the fact that the number of eggs produced by a mature female plaice is only about one-fifth of that produced by a mature female flounder, and that this year about half of our available space was occupied by plaice, while the previous year it was wholly devoted to flounders. The average spawning plaice is also considerably larger than the average spawning flounder, and, therefore, fewer adults can be kept. It therefore follows, that with the limited tank accommodation at Piel, if we continue to substitute plaice for flounder, the number of eggs for incubation will decrease. Any such decrease in the numbers of fry set free is, however, more than compensated for by the higher value of the plaice.

As stated in last year's report, mature plaice are now very scarce in Lancashire waters. It has been necessary, therefore, to obtain the stock of spawning fish from the preserved waters on the South coast of Scotland. Permission to trawl in Luce Bay was very courteously given by the Fishery Board for Scotland, and in the autumn of 1901 and 1902 visits were made to that bay with much success, and a sufficient number of mature fish were collected. It is to be regretted that such an area, suitable for the habitat of mature plaice, and at the same time able to be strictly preserved by the Lancashire and Western Sea

Fisheries Committee, does not exist in the coastal waters under their control. We have evidence which seems to indicate that this fish is now becoming less abundant than formerly on the West coast. The difficulty of securing mature specimens in any quantity is mentioned above, and there is reason to think that young plaice (1st and 2nd year fish) are also undergoing reduction in the in-shore waters.* The remedial measures in these circumstances easiest of attainment appear to be: (1) Protection of the young fish on the in-shore grounds; (2) The imposition of some suitable size limit; (3) A hatchery in conjunction with some preserved area. Of these remedies (1) is difficult to secure, for although much evidence in favour of the preservation of certain in-shore areas frequented by young plaice has been obtained by the Committee, powers to effect this have not been granted them; (2) requires legislation of which there is still no immediate prospect. Hatching in conjunction with a preserved area is therefore the only (present) practicable remedial measure, and this we have endeavoured to adopt by making use of the Piel hatchery and the preserved waters of the Fishery Board for Scotland in Luce Bay. Such a measure obviously requires the co-operation of two of the authorities concerned in the regulation of the Irish Sea Fisheries—the Fishery Board for Scotland and the Lancashire and Western Sea Fisheries Committee—and this co-operation we have fortunately been able to secure. To develop the method further will, however, require an extension of the resources at our command as far as the Piel hatchery is concerned. It is found to be impossible to keep the adult fish in our small tanks from one hatching season to another. An open air pond on similar lines to the one at the Fishery Board for Scot-

* See this Report, p. 80-2.

land's Hatchery, Bay of Nigg, near Aberdeen, would be of immense value in all our hatching and rearing work. Once the pond was stocked with fish, re-stocking would be unnecessary except, perhaps, occasionally to compensate for death due to unavoidable causes. The pond would also encourage the growth of natural food for the larvæ, and thus place us, to some extent at least, beyond the influences of weather and tides which so readily affect the floating food supply of the sea in a neighbourhood such as that of Piel.

During the season of 1902 we had 60 plaice and 150 flounders in the tanks. The latter were collected in Barrow Channel, as in former years, by Mr. Wright. The prolonged period of cold weather in February, and the consequent low temperature of the air and sea, had considerable effect in retarding the maturing of the fish. The first fertilised eggs were collected on March 6th, and the last on May 21st. During the spawning period over thirteen millions of eggs were collected and incubated, and these eggs produced nearly twelve millions of fry, which were set free about the centre of Morecambe Bay, a locality where we have found, in various surface tow-nettings, the fry of cod and plaice naturally hatched in the sea. In the case of the flounder the period of incubation varied from eleven days at the beginning of the season to seven days at the end, because of the increase of temperature. The plaice at the beginning of the season took seventeen days to incubate, and fifteen towards the end. The loss of eggs during incubation from all causes was slightly over 11 per cent.

The following tables show the number of eggs collected and fry set free, and also the specific gravity* and tem-

* The figures given are simply the uncorrected readings taken with the Kiel areometers.

perature of the sea water in the hatching boxes during the spawning season. The temperature of the air in the Tank House at noon of each day is also given.

Plaice.

			Eggs Collected.	Fry Set Free.			
March	6	...	40,000	35,500	...	April	1
,,	10	...	25,000	22,000	...	,,	,,
,,	13	...	40,000	35,000	...	,,	,,
,,	18	...	75,000	66,500	...	,,	9
,,	21	...	50,000	44,000	...	,,	,,
,,	24	...	75,000	67,000	...	,,	15
,,	26	...	75,000	66,500	...	,,	,,
,,	29	...	75,000	67,000	...	,,	,,
April	1	...	50,000	44,000	...	May	5
,,	5	...	50,000	44,000	...	,,	,,
,,	7	...	50,000	44,500	...	,,	,,
,,	11	...	68,000	61,000	...	,,	,,
,,	15	...	70,000	62,000	...	,,	,,
,,	19	...	50,000	44,200	...	,,	,,
,,	23	...	50,000	44,300	...	,,	21
,,	26	...	40,000	35,500	...	,,	,,
,,	28	...	40,000	35,600	...	,,	,,
May	3	...	40,000	35,600	...	,,	,,
,,	6	...	60,000	53,000	...	,,	,,
,,	10	...	60,000	53,200	...	June	3
,,	15	...	60,000	53,200	...	,,	,,
,,	21	...	70,000	62,000	...	,,	,,
Total Eggs			1,213,000	1,075,600	Total Fry		

Flounder.

		Eggs Collected.	Fry Set Free.		
March	6	... 157,000	139,000 ...	March	21
,,	10	... 314,000	278,500 ...	,,	,,
,,	13	... 157,000	139,000 ...	,,	,,
,,	18	... 485,000	430,000 ...	April	1
,,	21	... 400,000	355,000 ...	,,	,,
,,	24	... 786,000	697,400 ...	,,	9
,,	26	... 700,000	622,400 ...	,,	,,
,,	29	... 700,000	621,000 ...	,,	,,
April	1	... 1,300,000	1,153,000 ...	,,	15
,,	5	... 700,000	622,400 ...	,,	,,
,,	7	... 400,000	355,500 ...	,,	,,
,,	11	... 550,000	487,000 ...	May	5
,,	15	... 680,000	608,000 ...	,,	,,
,,	19	... 785,000	698,000 ...	,,	,,
,,	23	... 786,000	698,300 ...	,,	,,
,,	26	... 400,000	356,000 ...	,,	,,
,,	28	... 400,000	355,500 ...	,,	,,
May	3	... 600,000	532,000 ...	,,	21
,,	6	... 600,000	532,500 ...	,,	,,
,,	10	... 600,000	532,500 ...	,,	,,
,,	15	... 600,000	532,000 ...	,,	,,
Total Eggs		12,100,000	10,740,000	Total Fry.	

Total Number of Eggs 13,313,000

Total Number of Fry 11,815,600

Table shewing the Temperature and Specific Gravity of the Sea-water during Hatching Season.

Date.	Temp. of Sea.	Temp. of Air.	Specific Gravity.	Date.	Temp. of Sea.	Temp. of Air.	Specific Gravity.
	°C.	°C.			°C.	°C.	
Mar. 6	4·6	4·8	1·0260	April 22	8·8	10·4	1·0268
7	4·6	4·8	1·0260	23	8·8	10·4	1·0268
8	5·0	6·8	1·0260	24	9·2	10·6	1·0268
9	5·0	7·0	1·0260	25	9·6	11·0	1·0260
10	5·2	7·2	1·0268	26	9·4	11·2	1·0260
11	5·2	6·2	1·0268	27	9·2	9·2	1·0260
12	5·2	6·2	1·0268	28	8·8	8·0	1·0260
13	5·0	5·6	1·0260	29	9·2	9·2	1·0260
14	5·0	6·0	1·0260	30	9·2	9·2	1·0260
15	5·4	6·8	1·0268	May 1	9·2	9·6	1·0260
16	6·2	7·2	1·0268	2	9·2	9·8	1·0260
17	7·4	8·8	1·0262	3	9·2	10·0	1·0260
18	6·6	8·2	1·0262	4	9·2	10·2	1·0260
19	5·8	7·0	1·0262	5	9·2	10·0	1·0260
20	5·8	6·2	1·0262	6	9·2	9·6	1·0260
21	5·8	5·8	1·0262	7	8·6	8·8	1·0260
22	5·4	5·4	1·0268	8	8·6	8·8	1·0260
23	5·6	5·6	1·0262	9	9·0	9·2	1·0260
24	5·4	5·2	1·0260	10	9·0	9·4	1·0260
25	5·2	5·8	1·0260	11	9·2	9·8	1·0266
26	5·2	6·0	1·0260	12	9·0	9·8	1·0260
27	5·6	6·4	1·0260	13	8·8	9·8	1·0260
28	6·0	8·6	1·0260	14	9·0	10·0	1·0260
29	6·4	8·6	1·0260	15	9·2	9·2	1·0260
30	6·2	7·0	1·0260	16	9·2	9·4	1·0260
31	6·2	7·4	1·0268	17	9·4	10·0	1·0260
April 1	6·8	7·6	1·0268	18	9·2	9·8	1·0260
2	7·2	7·6	1·0268	19	9·2	9·8	1·0260
3	6·8	7·2	1·0266	20	9·0	9·2	1·0260
4	6·6	6·2	1·0268	21	9·4	10·4	1·0260
5	6·0	5·8	1·0268	22	9·8	10·4	1·0260
6	5·6	6·4	1·0268	23	10·0	11·8	1·0260
7	5·8	5·6	1·0268	24	10·2	10·8	1·0258
8	5·8	6·0	1·0268	25	10·4	11·4	1·0258
9	6·2	7·0	1·0268	26	10·8	11·4	1·0258
10	6·2	7·8	1·0268	27	11·0	13·4	1·0258
11	6·0	8·0	1·0268	28	11·0	14·0	1·0258
12	6·2	8·0	1·0268	29	11·0	13·6	1·0258
13	7·8	8·4	1·0268	30	11·0	12·8	1·0258
14	7·0	8·4	1·0268	31	11·2	13·4	1·0258
15	7·8	9·0	1·0268	June 1	11·4	14·0	1·0258
16	8·0	9·2	1·0268	2	11·8	14·0	1·0256
17	8·0	9·4	1·0268	3	12·4	16·8	1·0256
18	8·2	9.8	1·0268	4	12·4	14·6	1·0256
19	7·8	9·4	1·0268	5	12·4	13·2	1·0256
20	7·8	9·6	1·0268	6	12·4	13·2	1·0256
21	7·6	10·6	1·0268	7	12·4	13·2	1·0256

Trawlers and the Artificial Fertilization of Fish Ova.

By Andrew Scott.

Under the above title Mr. A. Meek, M.Sc., in his Report on the scientific investigations carried on under the Northumberland Sea Fisheries Committee for the year 1901, makes some statements regarding the fertilization of fish ova taken from fish caught in the course of commercial trawling, which appear to require some explanation and are at complete variance with the experience we have had in past years in our work in the Irish Sea. In a pamphlet published some time previously, Mr. Meek had given directions for the stripping of ripe fish caught in the trawl net, and for the fertilization of the ova, a method which was advocated by Professor McIntosh and others many years ago. This work was to be done by the masters of trawlers and the fertilized ova obtained were to be at once returned to the sea. In the report referred to Mr. Meek gives some account of the results obtained. A number of captains of trawlers had been carrying out this work and a report is given of the fish and ova dealt with by Captain Cappelman.

According to Mr. Meek, Captain Cappelman dealt himself with over 40 cod and 12 plaice, and from these fishes he obtained 120,000,000 cod ova and 2,000,000 plaice ova. This, the writer states, is a modest estimate of the ova dealt with. But a number of other captains had also been engaged in the work, and altogether, he estimates that as a result of the efforts of his Committee some 500,000,000 of fertilized ova had been returned to the North Sea. No particulars are given of the exact methods employed by the captains of the trawlers. We are safe, however, in assuming that they were similar to those employed by the captain and crew of our own fisheries steamer in the Irish Sea and elsewhere, for the purpose of obtaining spawn for the Piel hatchery. That is, the contents of the trawl net when emptied on deck are diligently worked over. Ripe female cod and plaice, as the case may be, are selected, and the mature eggs expelled by gentle pressure on the abdomen into a bucket of clean sea water. Ripe males are next secured and the milt expelled into the bucket amongst the eggs. The whole contents are then gently stirred and allowed to settle for a time. The unripe eggs fall to the bottom and by carefully pouring off the water into another bucket these are left behind. The floating eggs which come over in the water are then ready to be taken to the hatchery or returned to the sea. It must be remembered, however, that all floating eggs secured in this manner are not necessarily fertilized. We have found from actual experience that unfertilized plaice eggs may continue floating and remain fairly transparent for a whole week after being expelled from the fish.

If all the 40 cod and 12 plaice dealt with were females, then the cod apparently gave 3,000,000 eggs each and the plaice about 166,000.

These facts are sufficiently remarkable to those acquainted with the work which has been done on this subject to call for some explanation. The best estimates of the number of eggs contained in the ovaries of ripe female cod and plaice give from 3 to $6\frac{1}{2}$ millions in the case of the cod, and 148,000 to 487,000 in the case of the plaice, the exact number of course varying with the size of the fish and the locality where they were captured. Captain Cappelman, then, obtained by far the greater portion of the ovaries by stripping the fish. Now, it is well known that all the eggs present in the ovary of the cod and plaice do not become mature at the same time. In the case of the plaice the proportion is very much smaller than in the cod. As a result the spawning period of each individual fish lasts for some time. In the case of the plaice it may last a fortnight at least. As successive batches of eggs ripen they are expelled, until the whole ovaries are spent. The exact number of ripe eggs that are expelled at each successive emission is not known; but from the experience in the Piel hatchery, and our observations on the steamer lead us to the conclusion that it is much the same proportion in the case of trawled ripe fish, we conclude the number does not go beyond a few thousands in the case of the plaice. It is possible by means of pressure on the abdomen to expel 20,000 to 50,000 eggs at least which are fairly transparent, but only a small proportion of this number are perfectly mature and can be fertilized.

How obvious this is, is seen from a consideration of Dr. Fulton's work on the maturation of pelagic Teleostean eggs. Some time before the final ripening begins, the ovaries contain only small opaque ova. Even then their size is considerable. In plaice they extend so much into the body cavity, that the volume of the latter is reduced by one half, and the intestine and stomach are compressed into the anterior portion of the cavity. During maturation, as Dr. Fulton has shown, the eggs absorb water and undergo a considerable increase in size. The immature ovarian egg of the plaice has a volume of about 0·9276 cmm., whilst the ripe pelagic egg has a volume equal to 3·479 cmm. That is, during maturation the volume of the egg is increased nearly four times. Dr. Fulton says, "It is physically impossible for a female producing pelagic eggs to carry all her eggs in the mature distended state, because the volume of the ripe eggs may approximate to, or exceed the volume of the body of the fish."

It seems pretty evident that Mr. Meek has made the error of obtaining the numbers of eggs dealt with by simply multiplying the number of fish stripped by the theoretical average number of eggs in the unripe ovary, and did not actually have the numbers of eggs fertilized estimated. His numbers, therefore, require considerable reduction. We should say that instead of 500,000,000 a very much smaller number of eggs were really fertilized and returned alive to the sea.

We do not argue against the method advocated by Mr. Meek, but rather regard it as eminently useful and practical, if the crews of trawlers have sufficient time and zeal to carry it out. We think it useful, however, to point out its limitations.

On the Spawning of the Common Lobster.

By Andrew Scott.

The exact process by which the eggs of the common lobster of the British coasts are shed and conveyed to the swimmerets, appears to have been hitherto unknown. The following notes based on observations made at the Piel Hatchery may therefore be of interest.

In the first place a brief account of what is known regarding the process in some of the other crustacea is given.

Herrick in his great work on the American lobster,* which is closely related to our own form, states (p. 47) "I have not seen the process of egg extrusion and have no direct observations to record. It has, however, been witnessed in other crustacea where it is undoubtedly

* Bulletin of the United States Fish Commission, Vol. XV.

similar." He refers to the observations on the copulation of the river crayfish (*Potamobius fluviatilis*) made by Chantram and other naturalists, and also to Cano's account of the laying of the eggs in the crab *Maia*. References bearing indirectly on the subject are also given by Herrick.

Chantram's account of the extrusion of the eggs in the river crayfish is as follows:—"When the time comes for the extrusion of the eggs, the female raises herself upon her feet, and then the abdominal appendages secrete for a number of hours a grayish, somewhat viscous mass. She thereupon lies upon her back, bends her tail towards the opening of the oviducts so as to form a kind of cistern or chamber, into which, during the following night, the eggs are received as fast as they are expelled from the genital organs. This expulsion lasts from one to several hours."†

Cano gives the following account of the laying of the eggs in the Crab *Maia*. "The eggs at the time of ovulation, pass the opening of the receptaculum seminis, and are here invested with a coat of cement, which is secreted and held in the receptacle. The eggs . . . . are expelled one at a time by means of the vulvular apparatus . . . . The eggs thus ejected fall into the abdominal chamber. The female beats them about with repeated blows of the tail, while the pleopods, keeping them in continued agitation, make them converge to the centre of the abdominal pouch. The deposition of eggs is effected in *Maia* in the course of twenty-four hours."* The position of this crab during the extrusion of the eggs is not noted.

The Rev. T. R. R. Stebbing, in his book "A History of Recent Crustacea," ‡ gives the following reference, from

† Bulletin of the United States Fish Commission, Vol. XV., p. 36.

* *Op. cit.*, p. 49.

‡ Internat. Scientific Series, Vol. LXXIV.

Patrick Browne's "History of Jamaica," regarding the spawning of the land crab *Gecarcinus*. "The eggs are discharged from the body through two small round holes situated at the sides and about the middle of the under shell; these are only large enough to admit one at a time, and as they pass they are entangled in the branched capillaments . . . . to which they stick by means of their proper gluten, until the creatures reach the surf, where they wash 'em all off, and then they return back again to the mountains."

At the end of the lobster hatching and rearing experiments which were carried on during the past summer, the adult lobsters were retained and kept under observation. On October 9th one of a batch of five in one tank was seen to be in a restless condition and shortly afterwards it turned on to its back and remained perfectly still. Thinking the animal to be dead or dying we proceeded to remove it, when it was discovered to be shedding eggs. The process is as follows:—The lobster turns on to its back and by the aid of the two large claws and ridge of the abdomen makes a tripod of itself, the head being considerably higher than the posterior portion. The abdomen is then strongly flexed, forming a pocket, and the setæ on the edge of the abdominal segments make the space along the sides perfectly tight. A Λ shaped opening into the pocket is formed by the telson and the sixth abdominal segment. This opening, when the abdomen is flexed, is slightly posterior to the first pair of swimmerets. The eggs then flow from the two genital openings in a continuous stream, one at a time, and pass along at the bases of the last walking legs and into the opening of the "pocket." The course of the eggs into the "pocket" is further assisted by a constant pulsation of the first pair of swimmerets, causing an indraught, which carries them rapidly inside. None of the eggs are lost on the passage from the genital openings to the "pocket" unless the lobster is disturbed. As the eggs leave the oviducts they become coated with an adhesive substance which causes them to stick together and to the swimmerets. The period of oviposition in the lobster under observation was just over four hours. Half an hour after the eggs had ceased to flow the lobster righted itself and walked into a corner of the tank, eventually getting into a nearly perpendicular position, with the head downward. It remained in this position for the rest of the day. Next day it was walking about the bottom of the tank in the usual way of a berried lobster. That the adhesive power of the eggs was imparted to them before leaving the oviducts, was proved by collecting some just as they emerged from the genital openings. When these samples were placed in a glass of sea water and collected into a heap, they all became attached one to the other, and also to the glass. Moreover, the adhesive material only remains soft for a short time, as when the individual eggs were isolated and prevented from adhering to the glass, it was found that at the end of half an hour the adhesive property had completely disappeared. The eggs when extruded are quite soft and fall flat when removed from the water, the spherical state is regained immediately the eggs are placed in the water again. They are of an opaque dark green colour, with a thin transparent shell. The eggs measured in water so that the spherical condition was unaltered, were found to be 1·8 millimetre in diameter.

Another point now falls to be discussed, and that is, the frequency of spawning and moulting in the lobster. The lobster which came under observation at Piel was one of a batch collected at Bardsey Island in July, 1902. It was then bearing eggs which had been extruded sometime towards the end of the summer of 1901. These eggs commenced hatching early in August, 1902, and by the end of that month had all hatched. After an interval of less than six weeks, during which there was no possible chance of the shell being cast and escaping observation, another batch of eggs was extruded, without any intervening moult. That is, this lobster has definitely produced one batch of eggs each year, for two successive years, without moulting. Of the batch of five lobsters referred to at the beginning of this article, two moulted very soon after their eggs hatched and have produced no other eggs, two produced eggs without moulting, but only one was actually observed in the act, and the remaining one has done nothing.

Dr. H. C. Williamson in his valuable paper "Contributions to the life history of the edible crab,"* gives important information on the spawning and moulting of that crustacean, and also a summary of the opinions held by various zoologists on the same process in the lobster.

Dr. Williamson states: "A crab does not always cast immediately it hatches its eggs. It very often carries eggs two years in succession." And again the crab "Will keep on having successive batches of eggs until the supply of sperms is exhausted."

Herrick in his summary of observations on the American lobster (p. 222), states: "The lobster does not spawn oftener than once in two years. The spawning period is probably a biennial one, one set of eggs (summer eggs) being laid in July or August (at Woods Holl), and the following set in two years from that time. One has only to examine the ovary of a lobster which has just hatched a brood—that is one year from the time of last

* Eighteenth Annual Report, Fishery Board for Scotland, Part III.

spawning—to be convinced that annual spawning is an anatomical impossibility."

Ehrenbaum was of the opinion that the European lobster produced eggs only once in four years, and Fullarton considered that it did not spawn two years in succession. Prince on the other hand does not favour the theory of biennial spawning.

Herrick, in a footnote on p. 72, suggests: "The best way to test the question by experiment would be to take a female which had recently hatched a brood, and keep her alive until the following summer, when the next batch of eggs would be due, in case the spawning period is a biennial one." This experiment was conducted by Cunningham at Cornwall. Of five lobsters which had hatched their eggs under his observation, and which were placed in a floating box in September, soon after the eggs had hatched, one was found to be berried in October, one produced no eggs, though the ovary was ripe in the following February, two cast their shells, and one escaped. The experiment has also been carried out in America, and Herrick has quite recently published a paper entitled "The reproductive period of the lobster."* This paper deals with the American species, and gives some later views based upon direct experiments with the living animal. Herrick states: "The theory of biennial spawning is supported by a variety of testimony. The true answer to the question 'How often does the mature lobster lay her eggs?' is, therefore, 'Once in two years as a rule.' On June 19th, 1900, Mr. Vinal Edwards placed in a floating car thirty-six lobsters from which the old external eggs had been removed, fed them regularly, and on the first of each month following caught one of the animals

* U.S. Fish Commission Bulletin for 1901, pp. 161-166 (1902).

and preserved its ovaries. When the last survivor was taken, May 1st, 1901, just ten months and twelve days from the beginning of the experiment not one of the animals had laid eggs. Further an examination of the ovaries disclosed no evidence of absorption of the ova, or abnormal retardation of their growth, such as we might look for upon the theory of annual spawning—nothing in fact but a slow regular growth of the organs." Further, "The theory of biennial spawning is supported: (1) By the statistics of the fishery; (2) by the anatomy of the ovary of the adult female taken at different seasons; (3) by the ratio of growth of a given generation of ovarian ova for stated periods; (4) by observations on animals kept alive for long periods; (5) by the evidence of the rapid growth of ovarian eggs of spawners for any given year, during the height of the breeding season. It is to be expected that the rule to which the majority conforms has many exceptions in individual cases, for variation is the rule of life. It seems quite probable that occasionally a lobster may lay eggs in two consecutive seasons, and that in other cases the normal biennial period may even be prolonged, but I have nothing further to offer under this head."

Much of the evidence in support of Herrick's latest conclusions on the theory of biennial spawning appears to be based upon the experiment carried out by Mr. Edwards. This experiment was not carried out on the lines suggested by Herrick in his work on the lobster, and is not altogether a satisfactory one. There is nothing to show that the eggs carried by the lobsters at the beginning of the experiment, hatched out naturally and were therefore extruded during the previous year, and there was no obvious need to kill one lobster each month to discover whether it was going to extrude eggs or not. The better and more conclusive plan would have been to allow the eggs to hatch and then keep the whole of the series of adult females alive, till they extruded another batch of eggs. The lobsters killed in the early part of the experiment had little opportunity to produce again, and none were alive to extrude eggs at the end of one complete year.

The fact that one of Cunningham's batch of lobsters produced eggs a few weeks after the previous lot had hatched, and the further evidence obtained at Piel, shows quite clearly that the views held by Ehrenbaum and Fullarton are erroneous. If it be possible for the European lobster to extrude another series of eggs within a short period after the previous eggs hatch, there appears to be no anatomical reason why the American lobster cannot also do the same. The difference between the European and American lobster is very slight.

The conclusion which is forced upon one regarding the spawning and moulting, then, is that a female lobster may, and does occasionally, produce eggs for two years at least in succession, without moulting, possibly for a longer period, and that moulting, after the animal has become reproductive only occurs at intervals which will no doubt depend largely upon the various factors influencing the condition of the creature.

The difference between Spring and Autumn Herring.

By J. T. Jenkins, D.Sc., Ph.D.

(Lecturer in Biology, Hartley University College, Southampton).

In all districts where a great herring fishery exists there is evidence of two main spawning seasons, the one being in the spring, the other in the autumn, and in the present paper the terms "Spring-herring" and "Autumn-herring" are respectively applied to herring which spawn in the spring or autumn.

In the Irish Sea the herring fishery is relatively not of great importance, and the movements of the shoals have not been studied in detail. On the Lancashire coasts their movements are very uncertain, but in the southern portion of the district they are more regular.

"The principal shoals visit North Wales in October and November, some also early in May and June."* Spawning probably takes place here in the autumn or winter. The Isle of Man herring fishery is also carried on in the autumn, commencing in June and lasting till October. In the latter month spawning herring have been taken off Douglas.† There seems to be little or no evidence as to a spring spawning, but further information on the subject is necessary.

Considerable difference of opinion has existed as to whether (1) these two groups of herring constitute different races, and if this be granted, whether (2) such races exhibit any morphological differences which are capable of measurement.

With regard to the first question, the separation of herring into two distinct races, which spawn at different

* Herdman & Dawson: Fishes and Fisheries of the Irish Sea, p. 60.

† Holdsworth: Deep Sea Fishing and Fishing Boats, p. 539. London, 1874.

times in the year, we have two contradictory opinions, each of which has been maintained by competent investigators. Heincke believes that there are two distinct races, but the Scandinavian and Danish authorities contradict this.

In connection with this we have to decide whether the herring spawns more than once in the same year. From what is known of other fish one is led to decide in the negative. Heincke* is of opinion that spawn has never been found twice in the same year on the same spawning ground, which would be the case if the same herring spawned twice in one year.

Cunningham† directly contradicts this since he says that two spawning periods have undoubtedly been observed in one year in the same neighbourhood.

Matthews‡ also believes that herring spawn twice in the same year. He believes that the herring that spawn off Ballantrae in February and March, and those which spawn off Campbeltown in spring and then swim into Loch Fyne in the summer as spent herring, become ripe there, and spawn for the second time from August to the end of October.

If the difference between two successive spawning periods is always one year, then obviously spring herring will remain spring herring.

There is still another view as to the interval between two successive spawning periods. The Scandinavian§ and

* Naturgeschichte des Herings. Berlin, 1898. Text, p. 47.

† The Natural History of the Marketable Marine Fishes of the British Islands, p. 151. London, 1896.

‡ Fourth Ann. Rep. Scot. Fish. Bd., p. 61.

§ Trybom. Sillundersökningar vid Sveriges Vestkust. Hösten 1888. Berättelse till Kongl. Civildepartementet. Stockholm, 1889, p. 12; and Smitt, Om sillrasernas betydelse. Bihang till K. Svenska Vet. Akad. Handlingar, Band 14. Afd. IV. No. 12. Stockholm, 1888. p. 13.

Danish authors believe that a period of eighteen months elapses between two successive spawning periods in which case the spring herring of one year would become the autumn herring of the next, and the autumn herring of one year would become the spring herring of the next year but one.

Heincke vigorously contests this opinion. He says* if the interval between two successive spawning periods exceeded one year, then we should get an equal distribution of spawning herring in all months of the year. This he states does not actually occur. His argument, however, does not apply if the interval were approximately eighteen months, since we should then still have two principal spawning periods—in spring and autumn.

It is thus seen that considerable diversity of opinion exists as to the separation of the herring into two groups —autumn and spring spawning.

If it be granted, for the sake of argument, that such a separation really exists, it now remains to inquire into the alleged differences between such supposed races.

Heincke, in a colossal work already cited, has gone into great detail with regard to these differences, and has put forward a formula based upon body and head measurements by means of which he claims to be able to separate the two races.

Although the present paper is devoted to a criticism of Heincke's methods and results, it is more with a view of re-opening the whole question for discussion than of deprecating the conclusions of Heincke.

In the first place it is necessary to explain the "Formulæ" of Heincke, and the methods of measurement applied by him on which the formulæ are based, and according to which he differentiates herring into autumn and spring-spawning races.

* *op. cit.*, p. 49.

In the first instance Heincke made his measurements with regard to four characteristics. Subsequently he extended his observations to include a large number of characters; he found, nevertheless, that the four characters originally chosen by him gave him the most important results.

These four characters are:—

1. Distance of the dorsal fin from the end of the snout. Measured from the end of the snout with the mouth closed, to the root of the first fin ray of the dorsal fin. "D" in Heincke's Tables

2. Distance of the ventral fin from the end of the snout. Measured from the end of the snout with the mouth closed to the root of the first fin ray of the ventral fin. "V" in the Tables.

3. Distance of the Anus from the tip of the snout. "A" in the Tables.

4. Length of the base of the Anal fin. From the root of the first to the root of the last fin ray of the Anal fin. "An" in the Tables.

From these four measurements Heincke believed that he could distinguish spring from autumn-spawning herring, provided a sufficiently large number of individuals were taken and the average calculated, otherwise the individual variation would be too great.

The characteristics are always expressed by Heincke as relative and not as absolute measurements, and they are expressed as a ratio of the total length, inclusive of the caudal fin.

A comparison of a large number of measurements showed that

1.	The distance of the	dorsal	fin varied from	2·08 to 2·47
2.	,,	ventral	,,	1·97 to 2·28
3.	,,	anus	,,	1·41 to 1·65
4.	The length of the base of the anal fin from			12·5 to 7·5

In order to make comparisons easier the ratios expressing the distance of the dorsal fin from the tip of the snout are divided into four groups each of which is distinguished by a number:—

1. When the ratios varied from 2·08 to 2·17
2. ,, ,, ,, ,, 2·18 to 2·27
3. ,, ,, ,, ,, 2·28 to 2·37
4. ,, ,, ,, ,, 2·38 to 2·47

In a similar manner each of the other ratios was divided into four groups with the exception of the distance of the anus which was divided into five. To each of these groups descriptive numbers or letters were applied, viz.:—

Distance of Ventral Fin.		Distance of Anus.		Length of Anal Fin.	
a.	1·97 to 2·04	0	1·41 to 1·45	A.	80 to 92
b.	2·05 ,, 2·12	I.	1·46 ,, 1·50	B.	93 ,, 105
c.	2·13 ,, 2·20	II.	1·51 ,, 1·55	C.	106 ,, 118
d.	2·21 ,, 2·28	III.	1·56 ,, 1·60	D.	119 ,, 131
		IV.	1·61 ., 1·65		

In the first place it should be noted that the formulæ do not express what they are intended to, and that it is quite possible that they can convey false impressions.

For instance it is quite possible that two groups of spring herring, to each of which Heincke's average formula 2bII. applies, are really much more unlike one another than one of them is unlike a group of autumn herring to which Heincke's formula 2aI. applies.

This difference may theoretically be very great, as may be seen on reference to the following table:—

Formula.	Indices.		
	D.	V.	A.
2bII. Spring herring...........	2·18	2·12	1·55
,, ,, ...	2·27	2·05	1·51
2aI. Autumn herring...........	2·27	2·04	1·50

In every respect the second group of spring herring is more like the autumn herring group than it is like the first group of spring herring.

That this discrepancy actually occurs in Heincke's work may be seen on reference to the following table:—

	Indices.			
	Formula.	D.	V.	A.
Tab. 108* 13 Spring herring from the Dollart	2bII.	2·27	2·12	1·54
Tab. 136† 24 Spring herring from Stralsund...............	2bII.	2·20	2·05	1·53
Tab. 143‡ 35 Autumn herring from Gothland Bank	2aII.	2·20	2·03	1·53

* *op. cit.* Tab. u. Taf. p. 123.
† ,, ,, 149.
‡ ,, ,, 156.

From this it appears that the spring herring from Stralsund resemble the autumn herring of the Gothland Bank much more than they do another group of spring herring from the Dollart, and the difference between the two groups of spring herring is nowhere more marked than where the formulæ are similar, that is, in the case of the distance of the ventral fin. It would have been far better to have employed, instead of an arbitrary formula, either the averages themselves or to have effected a comparison by means of curves based on these averages.

Then it would be possible to form a true conception of the actual relationship of the various groups of herring which Heincke investigated, which is practically impossible under present conditions.

But it is even more correct to take the individual herring since Heincke himself writes (l. c. p. LVII.):—

"Das korperliche Bild, dass die einzelnen Rassen bieten, ist nicht minder interessant. Ihre Unterschiede von einander sind gering und erreichen in der Regel nicht diejenigen, die wir an verschiedenen Species der Gattung *Clupea* wahrnehmen. Aber sie sind nicht minder scharf und so bezeichnend ausgeprägt, dass jedes Individuum den deutlichen Stempel seiner Rasse (seines Stammes, seiner Familie) trägt. Und das nicht nur in einzelnen, wenigen Eigenschaften seines Körpers, sondern wie man annehmen muss, in allen Eigenschaften und auf jedem Stadium seiner Entwicklung."

Heincke summarises the results of his most recent investigations as to the differences between spring and autumn herring quite at the end of his book (*o. c.* Text 125-128). It is to be regretted that in Table 3 he has only grouped together a small number of groups of ripe spring and autumn herring for the purposes of comparison and these are just those which exhibit a difference in the formula with respect to the ratio of the distance of the ventral fin from the tip of the snout. According to this summary it appears that the average formula of spring herring is 2bII.; of autumn herring 2aI. or 2aII.

But suppose we now turn to the volume of Tables, p. 196-199, Table 193. Here we have a complete summary of the average of the body measurements of the various local forms, and it appears that the average formula of the autumn herring is sometimes 2bII. (*i.e.* the true spring herring formula), and that the average formula of the spring herring may be 2aI. or 2aII. (true autumn herring average formula).

In this Table there are eight groups of spring herring which do not possess the formula 2bII. They are:—

Tab. 130. East Coast of Scotland. 2aII. (Autumn herring formula).

Tab.	56.	Bergen Sommersild.	2bIII.	
,,	57.	,, Vaarsild.	2aII.	(Autumn herring formula).
,,	59.	Utsire ,,	2aII.	(,,).
,,	90.	Liimfjord.	1aI.	
,,	91.	,,	1bII.	
,,	137.	Stralsund.	2bIII.	
,,	18.	Schlei.	3bII*.	

With respect to autumn herring we have the following groups with incorrect formulæ :—

Tab.	105.	Terschelling.	2bII.	(Spring herring formula).
,,	97.	Mouth of the Elbe.	2bII.	(,,).
,,	101.	,,	2bII.	(,,).
,,	102.	,,	2bIII.	
,,	103.	Helgoland.	2bIII.	
,,	96.	W. of Sylt.	2bIII.	
,,	127.	Scotland, Fair Island.	2bII.	(Spring herring formula).
,,	129.	,, Peterhead.	1aII.	
,,	50.	Bohuslän.	1bII.	
,,	93.	Varberg.	1aI.	
,,	38.	Bay of Kiel.	2bII.	

This last group should not have been left out of the summary (Text p. 126), since they are not only herring from the Bay of Kiel but the formula is the average of 47 individuals and not as the other three groups only 30, 21 and 19, respectively, and the greater the number of individuals the greater the accuracy of the average formula.

Heincke himself writes, p. 126:—"Die Genauigkeit aller Mittelwerte einer Rasse hängt ab von der Zahl *n* der Individuen, aus denen das Mittel gezogen ist."

* In Tab. 193 this is given as 2. It should be 3 (see Tab. 18, p. 40. Index = 2·28).

Quite at the end of his work (p. 128) Heincke writes:—"Hiernach bekunden die von Petersen gegen mich ins Feld geführten Messungen von Herbst und Frühjahrsherigen aus den dänischen Gewässern, die ich in den Tab. LXXXI. bis LXXXIX. s. 105 bis 108 wiedergegeben habe, *einen unzweifelhaft sicheren Unterschied* zwischen den beiden Saisonrassen, indem bei den Frühjahrsheringen die Mittelformen 2bII., bei den Herbstheringen 2aII. und 2aI. vorkommen."

When these Tables are examined it is seen that Heincke is incorrect; Table 82 gives for 15 autumn herring from Varberg in the Kattegat the average formula 2bII., that is to say the average formula of spring herring. Further, in the examples cited above it is seen that the formulæ of Heincke do not hold good for the herring of the Danish waters, for example, in the case of Liimfjord (two groups) and Varberg.

To return to Heincke's summary (Table 193):—

SPRING HERRING.

Tables with correct average formula 2bII.	15	*i.e.* 65 %.
„ other „ „	8	*i.e.* 35 %.

AUTUMN HERRING.

Tables with correct average formula 2aI. or 2aII.	17	*i.e.* 60·7 %
„ other „ „	11	*i.e.* 39·3 %

Again, we have 30 body measurements of full herring from the Greifswalder Bodden given in Table 138 (p. 151), which herring were captured in November, 1891.

In Table 139 (p. 152) we have the skull measurements of 20 of these herring given.

In the summary of body measurements (pp. 196-199), the 30 Greifswalder herring are not given, but in the summary of skull measurements (Table 194, p. 200) these 20 examples from Table 139 are described as spring herring, this description must be based on skull measurements alone,* since they were *full herring taken in November*. The amount of importance that Heincke attaches to skull measurements may be gathered from the following extract (Text I. s. LVII.):—

"Man kann eine Rasse so gut an den äusseren Dimensionen des Körpers wie an den Bau der Wirbelsäule oder der *Gestalt des Schädels* oder dem besonderen Gange ihrer Entwickelung erkennen." And further (p. LVIII.):—"Man sieht sofort den grossen Unterschied der Rassen in den Schädeln, der jenem der Menschenrassen nicht nachsteht. Dem extrem *brachycephalen Schädel* des Islandherings steht zum Beispiel der ausgeprägt dolicocephale des Strömlings gegenüber."

As explained above, Heincke omitted the average formulæ of these Greifswalder herring from his summary of body measurements in Table 193.

If one refers to Table 138 (p. 151) it is seen that these herring possess the formula 2aII. (Indices D 2·24, V. 2·049, A. 1·53), that is an *autumn herring formula.*

Here, then, we have a peculiar instance of herring, which are "full" in November, possessing the skull of spring herring and the body of autumn herring.

Again Heincke describes (Table 127, pp. 142 and 143) 61 full herring from the Fair Islands as *autumn herring,* although they were taken in June and possess the spring herring formula 2bII. Fourteen other examples of the same shoal (Table 126, p. 141), possess the autumn herring formula 2aII.

Heincke found the correct autumn herring formula in

* P. 195:—"Die Mittel derjenigen Eigenschaften, die für eine sichere Unterscheidung der Lokalformen besonders wichtig sind, sind **fett gedruckt.**"

the case of ten herring (Table 141), from Bornholm, the average formula being 2aII. For 25 herring from Korsör (Table 73), the so-called autumn herring formula also holds good. If we, however, take the first ten of these for comparison with the ten Bornholm fish, we find that the formula no longer holds good. If Heincke had only received 10 herring from Korsör instead of 25, then he would have referred this "local race" to the spring herring with the average formula 2bII. (Indices D 2·25, V. 2·057, A. 1·53). When one takes a certain number of individuals from Heincke's tables for investigation, it becomes possible to change autumn into spring herring, and *vice versâ*, at any rate occasionally.

For instance take Table 23. Here we have 21 herring which give the average formula 2aII, that is the autumn herring formula. If, however, the first ten only are taken we get the average formula for spring herring 2bII. (Indices D. 2·19, V. 2·05, A. 1·54).

One is, therefore, from a consideration of Heincke's own tables, forced to the conclusion that neither measurements carried out on single specimens nor the average formula obtained by measurements of an indefinite number of individuals lead one to a certain and definite separation of herring into the two groups of autumn and spring herring.

Without going so far as to actually say that no such difference exists, it seems sufficiently obvious that more measurements are necessary to establish Heincke's arguments, and it is also obvious that the results of these new measurements must be differently expressed.

The Future of British Fisheries Investigation.

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

The past year has been noteworthy for two events, either of which may have an important influence upon the future course of scientific investigations bearing upon our national sea-fisheries. One of these was the announcement, on January 31st, that our Government had given its adhesion to the International Scheme of North Sea Investigation; and the second was the presentation to Parliament, and subsequent publication, of the Report of the Committee on Ichthyological Research. This Committee was appointed by the President of the Board of Trade on August 13th, 1901, and meetings were held at which witnesses were examined and results discussed during the twelve months from September, 1901, to September, 1902. The Report of the Committee was signed and sent to the President on October 18th, 1902, was laid before both Houses of Parliament early in December, and was issued as a parliamentary paper about the end of the year.

At two successive annual meetings (11th June, 1901, and 10th June, 1902) of the Sea-Fisheries Authorities at the Board of Trade, the President (Mr. Gerald Balfour) has referred to the appointment of the Ichthyological Committee, has taken credit for the comprehensive scope of the terms of reference, and has given as a reason for postponing the consideration of various important questions connected with sea-fisheries investigation that these matters were being considered by the Ichthyological Committee, and that he must await the Report.

His words at the last meeting are so important, and so re-assuring as to the future prospects of fisheries work, that it is pleasant to recall them. On the 10th June, 1902, in replying to the arguments put forward by the Northumberland, the North Eastern, the Devon and the Lancashire and Western Committees in favour of "The establishment and maintenance by the Government of one or more laboratories for carrying on the work of fishery research, or, failing that, the provision from Imperial sources of the Funds necessary to render more efficient and useful the laboratories which at present exist," the President (Official Report, p. 18) said:—

"I have listened with great interest to the observations that have been made, and for myself I have great sympathy with the remarks that have been addressed to me upon this subject. At the same time I would refrain at present from expressing any final opinion upon the matter, and especially upon the matter in detail, and for this reason, that it is one of the subjects which, as I observed in my opening remarks, comes so clearly within the reference of the Ichthyological Research Committee that it is really necessary to wait for the report of that Committee before we make up our minds what ought to be done. But you may be sure that, so far as my influence is concerned, if anything can be done in pursuance of the report of that Committee to assist scientific investigation by giving aid to laboratories or otherwise, I should be most happy if that result could be achieved." While we must approve of Mr. Balfour's caution, in the earlier part of this statement, in refraining from expressing more than "great sympathy" until he had before him the report of the Ichthyological Research Committee, we may all rejoice, now that that Committee has reported favourably, at the declaration he makes in his final sentence that his influence will be given in backing up any recommendation in the report that State aid should be given to laboratories for scientific fisheries investigation.

With that promise from the President of the Board of Trade, and in view of the strong recommendations in the report of the Ichthyological Committee, there can surely be no doubt that the Board of Trade, either alone or supported by all the fishery organisations of the country, will without further delay urge upon Parliament the necessity of taking immediate steps, and, if required, legislation, in order to subsidise the necessary laboratories under the direction of a Fisheries Council for England. That is only one of a series of definite recommendations made by the Ichthyological Committee with the object of organising a comprehensive national scheme of fisheries investigation, and in view of the attention which the President has directed to the report of that Committee at the Statutory meetings of the Sea-Fisheries Authorities, it will be well to consider in some detail what these recommendations are.

As the Report shows, the Ichthyological Committee considered it their duty to inquire very carefully into the details of the (then) proposed international scheme for the investigation of the North Sea, as given in the publications of the Christiania Conference of 1901. The Christiania programme, supplemented by the evidence of witnesses and experts, was the only information then available, and it is that programme which is discussed and alluded to in various parts of the "Blue Book" issued by the Ichthyological Committee. The examination of important witnesses, now before the public in the pages of the Blue Book, makes it evident that there is great diversity of opinion amongst scientific experts (both biological and hydrographical) in this country, as to:—

(1) The best methods of carrying out the Christiania programme;

(2) The reliability of any results obtained;

(3) The applicability of such results to our British Sea-Fisheries.

Under these circumstances it is not surprising that the Ichthyological Committee, on May 29th (see Report, p. xxii.), requested their four scientific or expert members to go into these questions as a Sub-committee, and draw up a memorandum.

It is scarcely necessary to point out that the clearest distinction must be drawn between the international scheme (1) as a piece of pure scientific research, and (2) as fisheries investigation which will solve practically and within a given time, and by given means, certain questions of importance to British industries. Of the interest and importance, to scientific men, of the scheme as a piece of pure research there ought to be, and probably there is, no doubt. Speaking for myself for the moment, I am in thorough sympathy with the scheme from that point of view. It is just the kind of oceanographic research that I think most desirable and fascinating, and which I believe will lead to qualitative results of great interest to biologists, and, I suppose, also to hydrographers. But there is the greatest difference between (1) such qualitative results, which add certain new facts to science, and in regard to the economic importance of which all that can be said is that each and every scientific fact will some day find its application and may at any moment become of real importance to mankind, and (2) immediate quantitative results given as the outcome of investigations directed to particular practical problems. It is from the latter point of view that there seem grave reasons to doubt the adequacy and practical utility of the international scheme.

If the officials who have advised our Government to take part in the scheme will declare that they regard it merely as a piece of scientific investigation undertaken jointly with certain foreign savants, with the object of obtaining scientific data, and in the hope that the knowledge so acquired may possibly throw light on some of our fishery problems, then I, for one, will cordially approve of the enlightened action of our Government in supporting scientific research to that extent. But I fear that those who have promoted the scheme will make no such statement. If we may trust newspaper reports the Government have made it clear that they have been induced to join (1) in the hope of getting international regulation of the fisheries, which is remote, and even if attained would be of questionable importance, and (2) by the prospect of getting, within a couple of years, reliable results which will be of practical importance in connection with the fishery questions which affect Great Britain. How unlikely it is that any such results will be obtained can only be realised by those who have considerable experience of the irregularity of distribution of fish and other living things in the sea.

The scheme, as formulated in the Christiania programme, is a scientific investigation which is purely experimental, and which it will be very interesting to watch. But there is absolutely no certainty about the results. There is not even a reasonable probability that the work will lead to any conclusions of economic importance. The report of the Ichthyological Committee has made this clear, especially to naturalists and practical trawlers who have their own experience to judge from. The Committee states that the "fundamental practical problem at the present time is to establish the fact of an increased or decreased yield of the fisheries within the available area of supply, and the most pressing part of this problem relates to the more sedentary and local fish, such as flat fish." That, it will be generally agreed, is what we in England want, and moreover it is obvious that, as the Committee reports, "To establish the fact of an increase or decrease of the fisheries, information must be obtained as to the amount of fish caught on particular grounds by vessels sufficiently numerous to supply data representative of the total yield." The method in all such investigations must be the one of taking adequate samples and drawing conclusions from these samples. "It follows that any scheme of research, however elaborately planned or carefully carried out, will fail in its object if the samples are not taken over a sufficiently large area, and at sufficiently frequent intervals, to be truly representative of the area and period which they are supposed to represent." Now, we have ready to our hand in the cargoes of fish landed at our ports by the commercial fishing fleets, samples incomparably larger, more numerous, and more frequently and regularly taken than those of any number of specially equipped vessels likely to be put on our seas by any European Governments. It is one of the recommendations of the Ichthyological Committee that these "commercial samples" be made available for scientific work, that statistical returns in the right form, giving all the particulars required, such, *e.g.*, as exact localities, be arranged for, and that officials be stationed at the principal fishing ports to inspect the catches and select any samples required for further examination in the laboratory.

It would be possible, perhaps, with a few special vessels, in a few years, to make an approximate fisheries survey of limited circumscribed areas such as the Irish Sea, the Clyde sea-area, or the English Channel, but not of the enormous area of the North Sea, which is at least twenty times the size of the Irish Sea.

Special vessels have, however, important work to do, which will obtain for us information supplementary to that derived from the fishing fleets. They should be sent to survey special localities, to investigate spawning grounds, nurseries where small fish congregate, and any other areas of importance in connection with particular problems. And when set on work of this kind no other duties such as periodic cruises, mainly of hydrographic importance, should be allowed to interrupt the progress and continuity of these investigations.

One of the chief features of the international scheme is that all the vessels of the participating countries shall undertake quarterly cruises along certain lines, taking hydrographic and other observations at fixed stations. It is clear from the evidence given before the Ichthyological Committee that there is at least considerable difference of opinion even amongst hydrographers as to the value of the observations obtained on such cruises, and what direct bearing they have upon the fishery problems in which this country is really interested it would be difficult to say. It may be practically important, if any reliable conclusions can be drawn from observations made three months apart, to the countries bordering on the Baltic, and possibly to those interested in the deep Norwegian Sea, to know something of the movements of bodies of water differing very slightly in temperature and in density; but the influence of such variations upon the habits and abundance of the flat fish in our shallow North Sea has still to be demonstrated, and must at the best be so indirect, so slight, and so inconstant as to be upset by storms, chance winds and floods bringing an influx of fresh water from the rivers.

The Ichthyological Committee had evidence from two eminent hydrographers, Dr. H. R. Mill and Captain Tizard, R.N., that both the surface and the deeper layers of water in a shallow area like the North Sea change in character very much, both as regards one place compared with another and the one place compared with itself, at different times. Now, quarterly cruises may obviously miss many such changes, and therefore conclusions drawn from the observations may be erroneous. Moreover, it is very doubtful whether the sedentary flat fish in which we in this country are primarily interested are affected by the conditions which will be observed on the quarterly cruises. For these and other reasons it is evident (1) that the quarterly cruises, as planned in the Christiania scheme, are not sufficiently numerous to give reliable results, and (2) that these hydrographic results, even if obtained, have little or no bearing upon our most important fishery problems. They are also open to the objection that once in three months they take the special steamers away from any particular investigation upon which they may be engaged for a period so indefinite that Captain Tizard estimated it at one week and Dr. Mill at three.

The international scheme, as laid out in the Christiania programme, is evidently based upon the hypothesis that sound conclusions may be drawn from samples, both hydrographical and biological, taken by the few special steamers making periodic traverses and surveys over great extents of sea. A consideration of the size of the areas to be covered, of the small number of vessels available, and of the limited time, makes it certain that the samples to be taken will be relatively far apart both in space and time. Now there is much evidence, both in the pages of the Ichthyological Committee's report and also in general biological literature, to shew that such samples may not be representative and are, therefore, unreliable because of the manner in which both the physical and the biological conditions may change within narrow limits. This is such a fundamental matter and has such an important bearing upon not only the present issue but upon all our future investigations that it will be well to illustrate it by a few instances.

Mr. Archer's detailed analysis of the observations taken by the Scottish Fishery Board in the Firth of Forth, has shewn that hauls taken under similar conditions on neighbouring areas may differ very considerably in their results; and the observations made from our own steamer in Luce Bay last November, given by Mr. Johnstone at a subsequent page of this report, demonstrate the same fact.

The importance of these observations in connection with any proposal to base conclusions upon the results of a comparatively small number of hauls taken at distant intervals over a relatively enormous area like the North Sea, must be obvious.

We find such an experienced navigator and hydrographer as Captain Tizard, R.N., Assistant Hydrographer to the Admiralty, stating in his evidence (in answer to Q. 2,125), that observations taken four times a year across the entrances to the North Sea would not show the nature of the water going in and out at all, that it would be necessary to take observations at much more frequent intervals (2,128), that in a place like the Channel between Dover and Calais the observing stations ought to be very close together, certainly not more than 3 or 4 miles apart (2,141), while in the space between the Orkneys and Norway stations say twenty miles apart would probably suffice, but that would have to be determined by experiment. Many others of Captain Tizard's answers on pp. 96-100 throw the gravest doubts upon the validity of conclusions drawn from such infrequent and scattered observations as are proposed in the Christiania programme.

Then again in Appendix V. (p. 153), we find Captain Tizard suggesting a scheme by which hydrographic observations should be taken at stations 10 miles apart along six sectional lines in the North Sea during February, May, August and November. We do not know whether these lines recommended by the Assistant Hydrographer are now being investigated under the international scheme, but in any case the results would seem open to many of the objections shown by Captain Tizard, in his evidence, to apply to all such occasional observations in a shallow area like the North Sea.

Dr. H. R. Mill, an expert in hydrography, who has himself conducted investigations on the physical conditions of the waters round our coast, speaking of the international investigations, of which he approved (Q. 1,663), said:—"I should say that after ten years it would be quite possible to get a very fair idea of the normal conditions of things." It would be interesting to know what he would expect to get after three years. Then, again, he considers (Q. 1,716) that quarterly cruises would not give sufficient information. In fact, Dr. Mill, although he recommends the international scheme, and was himself one of the British delegates to the Christiania Conference, evidently from his answers (p. 74, &c.), does not consider that the observations taken in accordance with the programme will be sufficient to enable us to base sound conclusions within the limited time.

It is important to notice also that the two expert witnesses who have had most experience of practical fisheries investigations and of work at sea, viz., Dr. T. W. Fulton, of the Fishery Board for Scotland, and Mr. E. W. L. Holt, of the Irish Board, are neither of them favourable to the international scheme, and do not think that it is likely to give us, within the specified time, results that will be useful in connection with our British Fisheries. Dr. Fulton (Q. 198) says:—"I am quite convinced that at the end of five years sufficient information to say whether there is a decrease of the fish supply of the North Sea, on the fishing grounds there, could not be obtained."

There are other witnesses whose evidence is given in the Ichthyological Committee's report, and who expressed full approval of the international scheme, but I do not think that it can be said that any of these are men with the practical experience of Tizard, Fulton and Holt. It is clear, then, that the argument in the Memorandum drawn up by some of the Committee is supported by the evidence of some of the most important witnesses; and under these circumstances many must sympathise with the view expressed by Professor Ray Lankester, when, in his evidence, he said:—"I should much prefer to see public money expended on a complete survey of the British Seas, say, to the 100 fathom line all round the British coast, to money being expended on this international arrangement."

Our conclusion, then, is that the international scheme, although an interesting scientific investigation, which may obtain results of great importance to the sciences of hydrography and biology, is, from the point of view of our English fisheries, an expensive experiment which is unlikely to yield reliable results of practical importance, within a reasonable time. The programme has not the appearance of having been devised with a view to the elucidation of our pressing fisheries problems, such as those of the flat fish, and it may well be doubted whether the quarterly cruises and other periodic surveys will yield results upon which legislation can be based.

The Ichthyological Committee, in the constructive part of their report, recommended a National Scheme of fisheries research and organisation, into the constituent elements and functions of which they enter in considerable detail. This scheme provides what has long been felt and often expressed as a great need in England, viz., a Central Fisheries Board, having at its command laboratories, vessels and scientific men, and it also endeavours to ensure the sympathy and help of the District Committees by giving them some representation on the Central body.

The points dealt with in the report are (1) Statistics, (2) Expert Staff, (3) Laboratories, (4) Vessels, (5) Central Authority, and (6) Co-operation with Scotland and Ireland; and the recommendations under these heads may be briefly summarised, with comments, as follows:—

(1) Statistics.—The Committee insist upon the necessity for much fuller and more accurate statistics as to the results of the commercial fisheries than are now supplied. Returns must be obtained from the masters of fishing vessels, and it is very desirable that full returns of all fish caught, giving the localities and other particulars, should be made compulsory.

(2) Expert Staff.—In the first place a staff of trained assistants is required at the principal fishing ports to deal with the returns obtained from the boats, to inspect the catches landed and to select samples for further ex-

amination. Certain observations can be made and certain particulars noted by such assistants carrying on statistical work at the ports, but it is not suggested that they need be laboratory biologists. Then, secondly, the samples selected along with the statistical and any other information should be sent for more detailed examination to the nearest marine laboratory, there to be dealt with by the Director and his scientific assistants.

(3) LABORATORIES.—The Ichthyological Committee point out that "the fishery interests of the East coast, the South coast and the West coast of England, respectively, are, to some extent, distinct," and they propose that these three coasts should be treated independently, each having its own marine laboratory, staff of workers, surveying vessel and representatives on the Central authority. It is recommended that, if possible, arrangements be made so that (1) the Marine Biological Association Laboratory at Plymouth be officially recognised as the head-quarters for scientific fisheries work on the South coast, say from the estuary of the Thames to the Bristol Channel; (2) that the Liverpool Marine Biological and Fishery Laboratories be similarly the centre for work on the West coast; and (3) that if no sufficiently large and well-equipped marine laboratory be already in existence on the East coast, a new institution be erected at Grimsby, possibly in connection with a fisheries museum, of which the Buckland collection might form the nucleus. This new East coast laboratory might possibly be more directly under the control of the Fisheries Department of the Board of Trade, and would furnish that Department with the laboratories, experimental tanks and scientific assistants, without which the officials cannot be expected to carry on original investigations.

The Ichthyological Committee, in making this recom-

Fig. 1.—Sketch map of the British Islands for the purpose of indicating the positions of the chief marine laboratories and sea-fish hatcheries, and the proposed division of the coast of England into three great fisheries districts—the East coast, the South and the West.

mendation in regard to laboratories for the three coasts, have, it will be observed, made use, so far as possible, of existing institutions, and propose to enlist the services of men who are already carrying on sea-fisheries investigations.

(4) VESSELS.—Each of the three coasts, it is proposed, should have a research or surveying steamer of the type of a modern steam trawler, specially fitted up for scientific investigations, and carrying on its work in connection with the laboratory of that coast. In the article which follows this will be found a scheme of investigation showing how such a vessel could be employed on the West coast.

(5) CENTRAL AUTHORITY.—The Ichthyological Committee recommend the formation of a "Fishery Council for England," consisting of representatives of (*a*) the Board of Trade, (*b*) the local Sea-Fisheries Authorities of the three coasts, and (*c*) the scientific men in charge of the three marine laboratories. This Fishery Council would be, to some extent, analogous to the Fishery Board for Scotland, but more suitable in other respects to England, where strictly local fisheries are more common than in Scotland, and where local needs have to be more closely studied. The Council would, it is hoped, be so representative as to unite the various fisheries interests and ensure the co-operation of the different organisations, local and central, now working at fishery problems. It is suggested that the Fishery Council should meet monthly or quarterly, as occasion may require, at the Board of Trade, to formulate and control schemes of investigation, to receive reports on work done on the three coasts, and corelate observations, to recommend the allocation of grants to the laboratories, and, generally, to report to Government, through the Board of Trade, on the needs and

results of the work carried on by the steamers and the laboratories.

(6) International Co-operation.—In order to secure uniformity of action between the fisheries organisations in England, Scotland and Ireland, to prevent overlapping of areas and of investigations, and to arrange as to any sub-division of work between the three countries, or with foreign nations, the Ichthyological Committee recommend that quarterly conferences should be held between representatives of the Fishery Council for England, the Fishery Board for Scotland, and the Irish Fishery Department. "The meetings of this conference would give an opportunity to the members of the three Central Authorities to compare notes, to obtain information as to what is being done in the three countries, and to make suggestions to the three Central Authorities as to what particular work should be undertaken by each" (Report, p. xv.). It is only to this extent—Quarterly Conferences—that the Ichthyological Committee have considered it practicable to constitute one Central Fisheries Department for the United Kingdom. We may quote finally paragraph 39 from the "Concluding Observations" of the Report:—"The Committee believe that by carrying out these recommendations the State would recognise, co-relate and control the work of the existing independent organisations in the United Kingdom, and would build up a scheme of Fishery Research of a thoroughly practical character, centring, as regards England, in the Board of Trade, and, at the same time, in intimate contact with the fishing trade, the district committees, and the scientific laboratories round the coast" (p. xviii.).

Scheme for the Investigation of the Irish Sea.

(As drawn up by Professor W. A. Herdman, F.R.S., for the Ichthyological Research Committee).

The suggestion, which I have made on several occasions, that a detailed scientific survey of the Irish Sea should be undertaken either by a Central Fisheries Department or by the Lancashire District Committee in co-operation with the Irish Fisheries Department, was first proposed in 1892, and was printed, in part, in my first Annual Report. More recently it was drawn up in further detail, and forms a portion of the Report for 1900. But as I had occasion last winter to revise and enlarge the scheme considerably at the request of the Committee on Ichthyological Research, who desired that I should lay a detailed programme before them, and as the matter concerns Lancashire primarily, I think it well to reprint here the essential part of what was submitted to that Departmental Committee, with a few slight additions.

It is generally agreed, I think, that if one steamer is to carry on all the work of our enlarged district, and if police work is to be regarded as the first duty, then sufficient time does not remain in which to carry out an adequate programme of scientific investigation. The following scheme is, therefore, drawn up on the basis that one steamer would be devoted to scientific and statistical work alone in the Irish Sea. It would be better still if one such steamer from the Lancashire side could collaborate with another from the Irish coast. In addition to this work at sea by the steamer there is much that must be done on shore at the ports of landing in order to obtain the fullest and most reliable information as to the catches of the commercial fleets from the different grounds in the area.

I assume that what we stand most in need of at present is full and accurate statistics in regard to our fisheries, and much more detailed information than we have as to the distribution round the coast both of fishes in all stages of growth, and also of the lower animals with which they are associated, and upon which they feed. I consider that what is necessary to give us that information is the nearest approximation we can make to a census of certain parts of our seas, beginning with the territorial waters and those off-shore grounds that supply them, and are definitely related to them. The work would be partly of a statistical nature, and partly scientific observations and investigations, and it seems clear that it is only by such a combination of methods that we can hope to settle many important fishery questions. My contention, then, is that such an investigation of our seas must be made, that it is urgent and should be made as soon as possible, and that the Irish Sea is favourably situated to be made a test case before undertaking the much wider and more difficult expanse of the North Sea, complicated by international questions. The Irish Sea is of moderate and manageable dimensions.* It is all bounded by British territory and by sea fisheries authorities, which might agree as to regulations. Its depths and the nature of its bottom deposits are most varied. It is a "self-contained" fish area, containing spawning banks, feeding grounds, and "nurseries." It has several laboratories (Liverpool, Dublin, Port Erin, and Piel) situated on its borders, which would form convenient centres for investigation, and it is controlled

* Its wider area north of Holyhead contains about 10,000 square miles, and is about one-twentieth part of the area of the North Sea.

by powerful sea-fisheries authorities, two of which, Lancashire and Ireland, might possibly be enabled to combine to carry out the work.

In this scheme, then, I suppose that a steamer of the size of a modern steam trawler, equipped with the necessary gear and apparatus, and having two or more scientific men on board, should devote all her time to the exploration of the Irish Sea. Such a vessel would cost about £6,000 to £8,000 to purchase, and the cost of running her would be about £2,000 a year. I take the month as the unit of time, and consider that every observing station must be visited twelve times in the year. If we plan four weekly voyages to different parts of the area in each month, and lay out four days' work in each week, that will allow for occasional days off for coaling, etc., and will give some extra working time in fine months, which could be devoted to further exploration outside the fixed programme. Bad weather will, no doubt, occasionally interfere, but it may reasonably be expected that in most months it will be possible to work on at least sixteen days.

Two kinds of work at sea, in addition to the commercial statistics obtained on shore, should be distinguished:—

1. The systematic statistical work, consisting of trawling and tow-netting along certain fixed lines, always with the same apparatus, on the same ground and at regular intervals. This work would be kept in close touch with the results obtained from the fishing fleets. Incidentally it would yield valuable information as to the efficiency of apparatus and the validity of the samples, which in our small area would be relatively numerous and taken at no great distance apart. Physical observations and quantitative plankton work would be carried on along with the trawling at each station.

2. General exploration, such as faunistic work, the tracing of areas of the sea bottom, the surveying of spawning and rearing grounds, the determination of the distribution of invertebrata and of fishes, and the investigation of specific points upon which information was required, such as the presence of full herring at certain times in Cardigan Bay. The programme for this work would necessarily be elastic, and could only be undertaken when it did not interfere with the fixed observations under 1.

Provisional Arrangement of the Work.

It is proposed that in each month the first week should be devoted to work in the important waters round the Isle of Man, the second to the deep water off Anglesey, the third to Cardigan Bay and the coast of Wales, and the fourth to the shallow in-shore waters of the Lancashire and Cheshire coasts.

First Week.

First Day.—Start from Fleetwood and steam west till the 20 fathom line is reached, about 35 miles. This is the region known as the "Hole," a very important spawning ground for plaice and other flat fish. The vessel should now take three hauls of the fish trawl, each of two hours duration, along lines running east and west, at depths of 20 to 25 fathoms. After the last of these, a short haul should also be taken over a part of the same ground with a shrimp trawl, in order to obtain smaller fish and compare results. Plankton nets will also be used simultaneously with the trawl, and physical observations will be taken at the beginning and end of each haul. The vessel will lie for the night in Port St. Mary Harbour.

Second Day.—The vessel will steam south to the deep water lying south and south-west of the Calf Island, which we know to be the spawning ground of cod, hake, haddock, and other fish. Three hauls with the fish trawl and one with the shrimp trawl should be taken along lines running north and south in water of depths of from 30 to 50 fathoms. Plankton nets and physical observations as before. Vessel to lie for night, according to weather, in Port St. Mary, Port Erin, or Piel harbours.

Third Day.—The vessel will steam to deep water lying west of Isle of Man, and take two hauls of the fish trawl and one of the shrimp net on the "reamy" ground, where the sole, the turbot, and the brill spawn, at depths of 30 to 50 fathoms, and one haul of the fish trawl on the mud at a depth of 70 to 80 fathoms. The vessel will then run further to the north and take two drags in the middle of the channel between Point of Ayre and the Mull of Galloway, at a depth of 20 to 30 fathoms. Plankton and physical observations as before at each station.

Fourth Day.—After spending the night at either Peel or Ramsey, according to the wind, the vessel will trawl from Ayre Point towards St. Bees Head, along the 20 fathom line, and then south from King William's Bank in the muddy depression of over 20 fathoms, also along the Bahama Bank, off Maughold Head. Two hauls of the fish trawl should be taken at each of these localities. Plankton and physical observations as before.

That finishes the statistical trawling investigation for that week, and the vessel will then, according to circumstances, either return to Fleetwood to land material and refit, or will stay out longer exploring the spawning grounds, etc., and doing other general faunistic work.

Second Week.

First Day.—Start from Fleetwood and steam south-west to the 20 fathom line opposite the mouth of the Ribble (26 miles), where we have found the tongue of deep water to be a spawning ground for haddock, whiting, etc. Take three hauls from east to west in depths of 20 to 30 fathoms, followed by one or two hauls of shrimp trawl, and run south to Holyhead harbour for night.

Second Day.—Start from Holyhead and trawl north-west in depths of 30 to 50 fathoms, so as to make a traverse across the channel by which water enters the Lancashire district from the south. Lie at night in Port Erin or Port St. Mary, according to wind.

Third Day.—Steam directly south from Calf Island towards Holyhead, and trawl in depths of 30 to 40 fathoms. Stay night in Holyhead.

Fourth Day.—Leave Holyhead and steam round Skerries to north coast of Anglesey. Take haul along the 20 fathom line towards Point Lynas. Then take two hauls of fish trawl in Red Wharf Bay and one of shrimp trawl, and run into Straits for the night. Any additional time that week could be spent in exploring Red Wharf and Beaumaris Bays and the neighbourhood. Remain week-end in Straits.

Third Week.

First Day.—Steam through Menai Straits to Carnarvon Bay, and spend rest of day in making several traverses of the shallow water between Anglesey and Bardsey Island. Lie for the night in St. Tudwell Roads.

Second Day. Continue south into Cardigan Bay, and trawl within the 20 fathom line south to New Quay or

Cardigan, staying for the night either in New Quay or Fishguard Bays.

Third Day.—Trawl across St. George's Channel from off St. David's Head to the Tuskar Rock and back, and stay night in Fishguard Bay.

Fourth Day.—Trawl northwards towards Bardsey Island in depths of 30 to 50 fathoms, and steam for night into Menai Straits.

Any additional time this week afforded by good weather can be spent in exploring northern parts of Cardigan and Carnarvon Bays, or drift-netting for herring at appropriate seasons. Stay week end in Straits.

Fourth Week.

(Lancashire and Cheshire Inshore Fishing Grounds).

First Day.—Leave Menai Straits, and work from the Great Orme's Head eastwards in the shallow water, within the 10 fathom line, to the mouth of the Dee. Take two hauls of the fish trawl between the Orme and the West Hoyle Bank, and two hauls of the shrimp trawl between the West Hoyle Bank and the Mersey. Stay night at New Brighton.

Second Day.—Take out a fishing boat for the day from New Brighton. Put a man on board her, and set her to work with the shrimp trawl in the shallow channels about Burbo Bank and Crosby Channel. Steamer to go further out and take hauls of fish trawl in Liverpool Bay within the ten-fathom line. Return to New Brighton for night, picking up fishing boat and getting results of day's work.

Third Day.—Steam to Formby Point, and start trawling northwards to Blackpool. Pick up a fishing boat for the day at New Brighton or Southport, put a man on board, and set it working shrimp trawl in the shallow water. Steamer to work outside the banks up to and including the Blackpool closed grounds, upon which one haul of fish trawl and one haul of shrimp trawl should be taken for comparison with hauls immediately before upon ground lying immediately to the south, off the Ribble. Pick up boat and get results, and then run to Fleetwood for night.

Fourth Day.—Leave Fleetwood for Morecambe Bay and Barrow Channel, taking a fishing boat in tow and setting her to work in the shallow water with shrimp trawl, while steamer uses fish trawl further out, as far north as estuary of Duddon, but all inside the 6 or 7 fathom line. In evening pick up boat and return to Fleetwood for week end, when general results of month's cruise would be seen to and put in order.

It would be well to send off certain collections when in port at the end of each week to the central laboratory in Liverpool.

The lines for trawling along each day in this scheme have been laid down on the chart, in consultation with Mr. Dawson, and along each line the same series of observations should be taken.

The observations made should include:—

(1) Drags with the fish trawl and shrimp trawl.

(2) Plankton collections with surface and bottom horizontal tow-nets, and also with quantitative vertical nets.

(3) Physical observations with thermometers, hydrometers, water-bottles, etc.

We may consider a few further details under each of these headings:—

I. Fish and Shrimp Trawling Observations.—(*a*) Drags should be made under strictly uniform conditions—that is, the same size, form and mesh of trawl net should always be used, and the drags should be of uniform length and duration, in order that they may be as strictly as possible comparable with one another. In addition to the fish trawl, it would be very useful at most stations if a haul of the shrimp trawl could also be taken.

(*b*) Every drag should be recorded, irrespective of the numbers of fish caught. A poor haul is just as important for statistical purposes as a successful one.

(*c*) All the fish caught should be measured, and the numbers of each kind and size accurately recorded on a form similar to the one appended.

(*d*) A number of individuals of each of the more important kinds of fish—such as plaice, sole, cod, haddock —from every haul should be weighed and measured separately. The ovaries should then be taken out and weighed, and the results recorded on the form. Anything noteworthy in the condition or appearance of the ovaries should be added. The stomachs should be opened and the contents noted.

(*e*) Mention should be made of any unusual fishes or invertebrata taken in the trawl, and also of any special abundance of common things such as star-fishes, crabs, molluscs, jellyfish, zoophytes, worms, or other fish food. Unusual specimens, or anything not recognised, should always be preserved for examination in the Liverpool Laboratory.

II. "Plankton" (or Tow-net) Collections.—Tow-nettings should be taken along with every drag of the fish trawl. One haul with a bottom and one with a surface net should be made on each occasion. Also one haul of the vertical net for quantitative work should be made at each station. These collections should be at once preserved according to instructions, and sent to the Liverpool Laboratory as soon as convenient after landing. Extra tow-nettings should be taken as frequently as possible. All such observations on the floating life of the sea (which includes the eggs and the microscopic food of many fishes) are most useful. Occasional hauls at particular seasons with a large mid-water net to ascertain the presence of larvæ and young fish would be most useful, but might form a part of the additional exploration work.

III. Physical Observations.—(*a*) Sea Temperatures.—Surface and bottom observations should be taken at the beginning and end of each drag, and should be read to 0·1° C. Bottom temperatures should be taken with a reversing thermometer. At certain stations in deep water, periodically, serial temperatures at 0, 2, 5, 10, 15, 20, 25, 30, 40, 50, 60, and 70 fathoms should be taken.

(*b*) Specific Gravity (density) of the Sea Water.—Surface and bottom observations should be taken at the beginning and end of each drag, and should be read to the fourth place of decimals. Bottom observations should be made on samples of the bottom water, taken with a Mill's bottle. The temperature and specific gravity should be taken simultaneously in the same sample of water. A sample (at least one litre) of the sea water should also be kept and sealed up in a stoppered bottle for examination of the salinity in the laboratory.

(*c*) Air Temperature.—One observation at the beginning of each drag should be taken for comparison with the sea temperature.

(*d*) Barometric Pressure.—One observation taken at the beginning of each drag is sufficient.

(*e*) Transparency and Colour of the Sea Water.—One observation should be taken at the beginning of each drag, and if any notable change has taken place in the water a second observation should be made at the end.

(*f*) Currents.—Drift bottles and other weighted floats should be set free to determine set of tides and other currents.

(*g*) Samples of the bottom deposits should be made and preserved for examination in the laboratory.

(*h*) The state of wind, tide, sea, weather, etc., should be recorded on the form supplied.

The above scheme applies only to the work on board the steamer. The observations at present carried on by the bailiffs in the in-shore waters should be continued, and weekly tow-nettings should be taken in each division of the district, and at the Piel and Port Erin Laboratories; and the fullest possible statistics must also be obtained from the commercial fishing boats. Notwithstanding the very great importance of such commercial statistics in connection with present or contemplated regulations, the system of collection is imperfect in various respects, and it is sometimes impossible to obtain reliable figures. The remedy is to place the collection of statistics in the hands of the local Sea-fisheries Committee who can obtain information as to every man, boy and boat fishing in their area.

The forms containing the results of the above observations should be posted to the Fisheries Laboratory, University College, Liverpool, with the least possible delay, as it is important that early information should be obtained of any unusual occurrence or any change in the distribution of fish and plankton throughout the district.

A copy of the form upon which the observations should be recorded was given in the report for 1900, at p. 30.

In addition to the regular statistical work planned for 16 days in each month, it is probable that the steamer in most months will be able to devote a few days to the work of exploring outside the stations laid down. Such exploration will be most valuable, both from the purely scientific and the industrial points of view. By such work our knowledge of spawning grounds, "nurseries," and the distribution of the fish in various stages will be advanced, and, moreover, light may be thrown upon the regular statistical observations.

Additional experimental work, such as the use of the large mid-water net, the pumping of water from different depths for plankton estimation, the experimental marking and liberation of fishes, and observations on the vitality of young fishes caught by different methods, might be undertaken on the days left free at the ends of the weeks.

In addition to the captain and crew (say twelve in all) necessary for working the vessel, and accustomed to the use of the trawling and other fishing gear, at least one and possibly two scientific assistants, the one a biologist and the other a chemist or physicist, should always be on board.

It is obvious that in carrying out this scheme, in addition to the work at sea, a considerable amount of work must be done on shore. Probably the most satisfactory and economical method of doing this would be to make use of the existing laboratories at Liverpool, Piel, Port Erin, and, if Ireland joins the scheme, at Dublin, and to employ the present staff with the additions that would be necessary.

The headings of the work in the laboratories would be as follows:—

(1) Tabulation and analysis of the records filled up on the steamer, and those obtained from the commercial fleet.

(2) Examination, estimation, and determination of the plankton collected.

(3) Examination of the fishes and invertebrates and other material retained as the result of the trawlings.

(4) Examination (microscopic and chemical) of the samples of sea bottoms.

(5) Physical and chemical work on the sea water. Determination of the densities and salinities of the water samples, and gas analyses of same.

(6) Co-relating results of the drift-bottle experiments.

(7) Preparation of charts, tables, and reports showing the distribution of animals, and other results.

Conclusion.

The northern area of the Irish Sea, from Liverpool to Holyhead and round the Isle of Man to Cumberland, has probably been more thoroughly worked,

(1) Topographically (as to bottom deposits, currents, etc.),

(2) Zoologically (by the Liverpool Marine Biology Committee),

(3) As to its Fisheries (by the Lancashire Sea Fisheries Committee), and is consequently probably better known in its details than any other area of similar size in British Seas.

It has, moreover, on its borders the marine laboratories mentioned above, with their staff of workers accustomed to the work of the locality, and hence seems, both from these circumstances and from its physical features, to be marked out as an area in which, with comparatively little new organisation, the proposed scheme of statistical and observational fisheries investigations could be carried out, in order to test:—

(1) How far it is possible to obtain an accurate statistical knowledge of the populations of a sea area; and

(2) Whether such knowledge leads to conclusions of importance in connection with the fishing industries.

On Some Experiments with "Drift Bottles."

By James Johnstone.

Two series of experiments have already been made from our Laboratory, with the object of determining the direction taken by small objects floating at the surface, in various parts of the Irish Sea. The results of these have been published in former reports.* In both series the portion of the Channel N. of Holyhead was mainly dealt with, and the general result was to indicate an apparent drift to the N. and N.E. on the E. side of the middle of the Channel, and a N. to W. drift towards Ireland on the W. side. The importance of the experiments was the probable indication of the general drift of fish eggs from the spawning grounds. It had been suspected, however, from some observations made by the late R. L. Ascroft and others on floating wreckage, that fish eggs spawned in the southern parts of the District might find their way into the shallow waters off the Lancashire and Cheshire coasts, and it became desirable to make some experiments to test this supposition. Accordingly, Prof. Herdman, while going out to Ceylon at the beginning of the year, set free some 200 bottles from the s.s. "Derbyshire," on his way down the Channel on board that vessel. The bottles were of the same size, and contained stamped and addressed postcards of the same description, as those used in the two former experiments. The experiment was very successful, and 118 of the bottles were subsequently picked up, and the postcards forwarded to the laboratory.

The bottles were set adrift in lots of ten, and the data obtained are given in the following Table :—

* Lancashire Sea-Fisheries Laboratory Reports for 1895 and 1898.

27TH DECEMBER, 1901.

Position and time when set free; age of tidal stream.	Place where found, and apparent time taken for the journey.	
Nos. 1—10. N.W. light ship, 1-30 a.m.; outgoing stream 1h. 35m.	Biggar Bank, Walney I.;	2 days
	Do. do.	4 do.
	W. shore, N. end Walney I.;	3 do.
	Do. do. do.	do.
	Do. do. do.	do.
Nos. 11—20. Between N.W. light ship and Little Orme Head, 2-0 a.m.; outgoing stream 2h. 5m.	W. side Walney I.;	4 days
	Do. do.	10 do.
	Opposite Biggar, Walney I.;	4 do.
	Hilpsford Pt., Walney I.;	4 do.
Nos. 21—30. Off Little Orme Head 2-30 a.m.; outgoing stream 2h. 35m.	Askam-in-Furness;	8 days
	Haverigg, Cumberland;	6 do.
	Walney I.;	16 do.
	N. end Walney I.;	6 do.
	Gutterby Pt., Cumberland;	13 do.
	N. Scale, Walney I.;	6 do.
	N. end, Walney I.;	5 do.
	Do. do.	do.
	Walney I.;	16 days
	Duddon Sands, Cumberland;	12 do.
Nos. 31—40. Off Puffin Island 3-0 a.m.; outgoing stream 3h. 5m.	Bootle, Cumberland;	13 days
	St. Bee's, do.	9 do.
	Do. do.	6 do.
	Bootle, do.	15 do.
Nos. 41—50. Off Point Lynus 3-30 a.m.; outgoing stream 3h. 35m.	Kirkby, N. Lancs.;	14 days
	Haverigg beach;	7 do.
	W. side Walney I.;	8 do.
	Silecroft, Cumberland;	7 do.
	Whitbeck, do.	9 do.
	River Duddon;	15 do.

Position and time when set free; age of tidal stream.	Place where found, and apparent time taken for the journey.
Nos. 51—60. Off middle Mouse Island 4-0 a.m.; outgoing stream 4h. 5m.	Gutterby Pt., Cumberland; 12 days Duddon Sands; 7 do. Annaside, Cumberland; 9 do. Do. do. 21 do. Haverigg; 7 do.
Nos. 61—70. E.N.E. of Skerries 4-30 a.m.; outgoing stream 4h. 35m.	Silecroft; 7 days Drigg, Cumberland; 10 do. Do. do. 10 do. Do. do. 10 do. Do. do. 10 do. Bootle, do. 10 do. Annaside; 13 do.
Nos. 71 - 80. N. of Skerries 4-45 a.m.; outgoing stream 4h. 50m.	Sellafield, Cumberland; 14 days Drigg; 9 do. Bootle, Cumberland; 10 do. Braystones, do. 13 do. Seascale, do. 10 do. Drigg; 10 do. Seascale; 10 do.
Nos. 81—90. N.W. of Skerries 5-0 a.m.; outgoing stream 5h. 5m.	Nethertown, Cumberland; 10 days Braystones; 10 days Nethertown; 10 do. Drigg; 9 do. Sellafield; 14 do. Braystones; 11 do. Seascale; 12 do
Nos. 91—100. W. of Skerries 5-15 a.m; outgoing stream 5h. 20m.	Flimby, near Maryport; 10 days St. Bee's Head; 9 do. Garton, near Whitehaven; 10 do. St. Bee's Head; 10 do

Position and time when set free; age of tidal stream.	Place where found, and apparent time taken for the journey.
Nos. 101—110. Off S. Stack 5-30 a.m.; slack water.	Parton, near Whitehaven; 8 days Do. do. 9 do. Workington, Cumberland; 8 do. Parton; 8 do. Do. 8 do. Whitehaven; 8 do. Do. 8 do.
Nos. 111—120. Holyhead I. bearing E.N.E. 6-0 a.m.; slack water.	Parton; 9 days Workington 8 do. Do. 8 do. Parton; 9 do. Workington; 9 do. St. Bee's Head; 10 do. Flimby; 9 do. Do. 10 do.
Nos. 121—130. Off Carnarvon Bay light ship 6-30 a.m.; ingoing stream 0h. 5m.	Seascale (found Sept. 5th, 1902). Drigg Sands; 9 days Seascale; 9 do. Parton; 12 do. St. Bee's Head; 9 do. Seascale; 9 do. Drigg Sands; 9 do. St. Bee's Head; 12 do. Seascale; 9 do.
Nos. 131—140. 8 miles W.S.W. of Carnarvon light ship 7-0 a.m.; ingoing stream 0h. 35m.	Bootle, Cumberland; 15 days Ravenglas, do. 8 do. Bootle, do. 13 do. Seascale; 10 do. Do. 10 do. Do. 9 do.
Nos. 141—150. 13m. S.W. by W. of Carnarvon light ship 7-30 a.m.; ingoing stream 1h. 5m.	Bootle, Cumberland; 11 days Ashton-with-Stodday, N. Lancs.; 11 days Bootle; 10 days Do. 10 do. Do. 9 do. Do. 11 do. Do. 11 do.

Position and time when set free; age of tidal stream.	Place where found, and apparent time taken for the journey.	
Nos. 151—160. Bardsey I. bearing S.S.E. 8-0 a.m.; ingoing stream 1h. 35m.	Bootle;	10 days
	Biggar, Walney I.;	10 do.
	Whitbeck;	9 do.
	Silverdale, Morecambe Bay;	25 do.
	Do. (found Feb. 2nd, 1902).	
	Haverigg;	9 days
	Middleton Towers, Heysham, N. Lancs.;	29 do.
Nos. 161—170. Off Bardsey I. 8-30 a.m.; ingoing stream 2h. 5m.	Cark Beck, Morecambe Bay;	25 days
	Sandylands, Morecambe;	31 do.
	N. end Walney I.;	9 do.
	Heysham Harbour works;	21 do.
Nos. 171—180. Cardigan Bay light vessel bearing S.S.E. 9-0 a.m.; ingoing stream 2h. 35m.	Piel, Barrow-in-Furness (found July 6th, 1902)	
	Carnforth, N. Lancs.;	14 days
	Shrobshire rocks, Heysham;	12 do.
	Middleton Towers, Heysham;	15 do.
Nos. 181—190. Off Cardigan Bay 10-0 a.m.; ingoing stream 3h. 35m.	Porthdavarch, Holyhead;	9 days
	South Shore sands, Blackpool;	10 do.
	Bispham, near Blackpool;	11 do.
	Heysham Harbour works;	26 do.
Nos. 191—200. Off Cardigan Bay 10-30 a.m.; ingoing stream 4h. 5m.	Lytham;.	12 days
	St.-Anne's-on-the-Sea;	12 do.
	South Shore, Blackpool;	12 do.
	Blackpool;	11 do.

Short descriptions only of the places where the bottles came ashore are given. In all cases the precise localities were given, and we are greatly indebted to the finders for the evident care which was taken in filling up the card, and in many cases volunteering further information.

The general results of the experiment are indicated on the sketch chart (fig. 2). The positions at which the various lots of bottles were set adrift are indicated roughly by the serial numbers in the lower portion, extending from the N.W. light ship to Cardigan Bay. The destinations of the bottles are given by the same numbers in the upper portion of the chart, the bracket indicating the portion of coast on which they were picked up. The line drawn from Maughold Head to the opening of Morecombe Bay indicates the place of junction or separation of the tidal streams in the North and St. George's Channel—the "head of the tide." When the chart and tables are compared it will be seen that:—

(1) 84% of the bottles picked up crossed this imaginary line and drifted on to the Furness and Cumberland coasts;

(2) 11% of the bottles found entered Morecambe Bay;

(3) 5% were stranded on the Lancashire coast between Blackpool and Lytham;

(4) And only one bottle, set free on station 19, failed to round Holyhead. This was found on the Holyhead coast about 2 miles from the place where the "Primrose Hill" was wrecked.

It is difficult to account for the varying destinations of the bottles set free in these experiments. Many factors determine their subsequent course, the chief of which are the wind and the direction and force of the tidal streams near the place where they were set free. In the absence of wind there seems no doubt that the course of a floating object might be predicted from a knowledge of the direction of the stream and the state of the tide. In general, in the

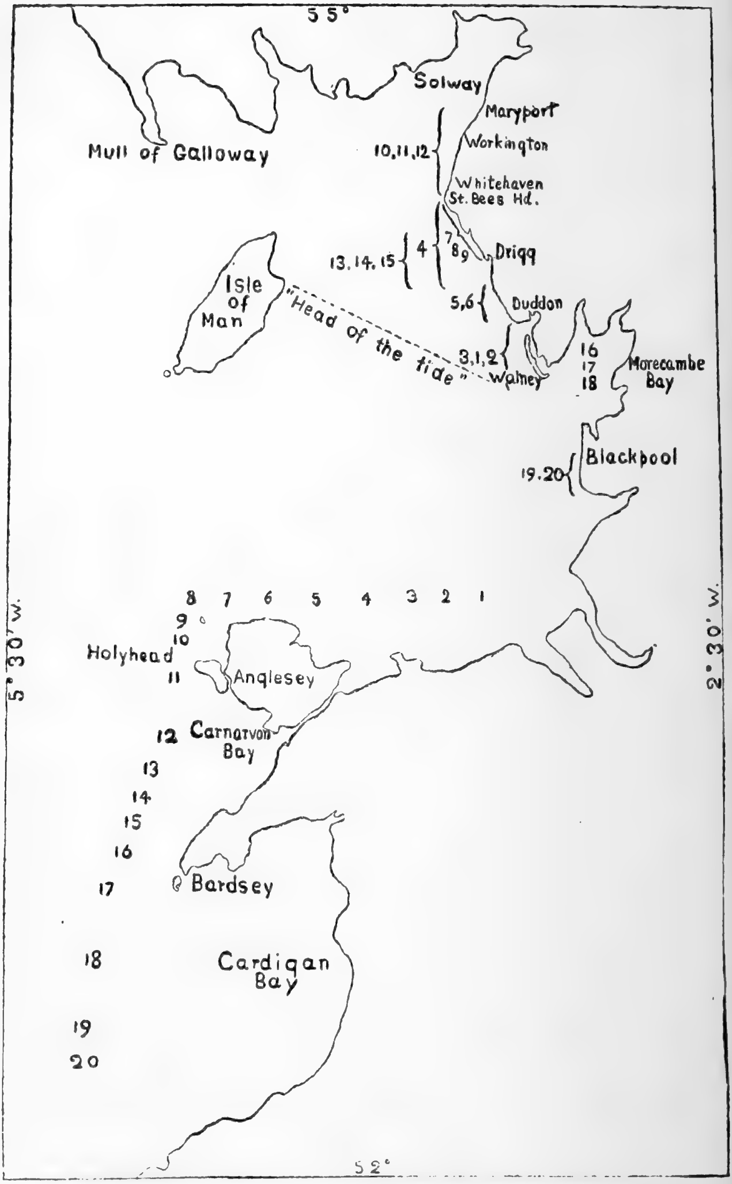


FIG. 2.—West Coast of England and Wales, shewing the localities of the drift bottles recovered.

fairway of the channel, a vessel will be carried about 9 miles by the stream during spring tides and about 6 miles during neaps. Near the land the velocity of the stream becomes much greater. The direction taken by the stream is now pretty well known in almost every part of the Irish Sea, and but for the varying influence of the wind, which it seems quite impossible to estimate, we should be able to trace the course of an object liberated at almost any place. We have tried to estimate the effect of the wind, and are much indebted to Mr. W. E. Plummer, of the Liverpool Dock Board's Observatory at Bidston for a complete series of readings of the Bidston instruments for the time during which most of the bottles were at sea.

It will be seen from the chart that there is a general northerly trend in the destination of the earlier lots of bottles. Nos. 1, 2, and 3, which were set free between the N.W. light ship and a point off Little Orme Head, have all been found either on Walney Island or in the Duddon Estuary. The direction of the streams about this point is nearly easterly and westerly, and we should expect that in the absence of wind the bottles would have oscillated backwards and forwards in this direction and finally gone ashore in the Mersey or Dee at the next spring tides. But the wind during the four days that these bottles were at sea came from the E.S.E. and S.W. with an average force of about 21 miles per hour, and it is this influence which determines the direction taken by them. Lot No. 4, of which four bottles were recovered, went as far north as St. Bee's Head.

The remaining bottles picked up seem to have behaved in a fairly regular way—Nos. 5 to 12 have gone successively further north. The number of bottles washed ashore on the portion of coast with Drigg as a centre is very noticeable. Mr. J. Grice, to whom we are indebted for much information, informs us that a strong current sets in towards Drigg and that "coasters in the know are always on the look out when anything goes down off Holyhead." The general direction and force of the wind remained much the same as before, but the bottles were liberated nearer the fairway of the Channel, and from No. 8 onwards they were subject to the influence of the (nearly) mid-channel streams and this accounts for their more northerly destination. From No. 12 onwards the destination changed to the south; thus the bottles liberated off Carnarvon Bay did not go so far N. as St. Bee's Head; those liberated off Bardsey Island (16 to 18) almost all went into Morecambe Bay, and the last two lots, set adrift near the southern limit of Cardigan Bay, got no further north than Blackpool. This is due, no doubt, to some extent, to the greater distance the bottles had to traverse, but also to the wind, which after the 10th January blew for a time from the E.N.E. to N.W.

The influence of the wind on the general drift which would follow from the direction of the tidal streams alone is also seen in the case of six bottles set free in a former experiment* by Mr. Scott. The data concerning these are given in the sketch chart (fig. 3). The bottles were set free about 10 miles west of Morecambe light ship on the same day; their destinations, the direction of the tidal streams and the general direction of the wind during the period when the bottles were apparently at sea, are marked on the chart. Under the influence of the tidal streams alone the bottles would probably have gone ashore near Blackpool or into Morecambe Bay, but the wind during the early part of the period when the bottles were adrift blew from the N., N.E., and N.W., and later on it shifted from N.W. through W. to S.W. The average

* Lancashire Sea Fisheries Laboratory Report for 1898, p. 30.

velocity during the period, 19th May—24th May was about 17 miles per hour, and during the whole period, 19th May—June 5th, about 15 miles per hour. The general influence of the wind was therefore to drive the bottles in a southerly direction, and this brought them within the influence of the stream setting into the Mersey estuary. Two bottles, however, seem to have remained longer at sea, and during

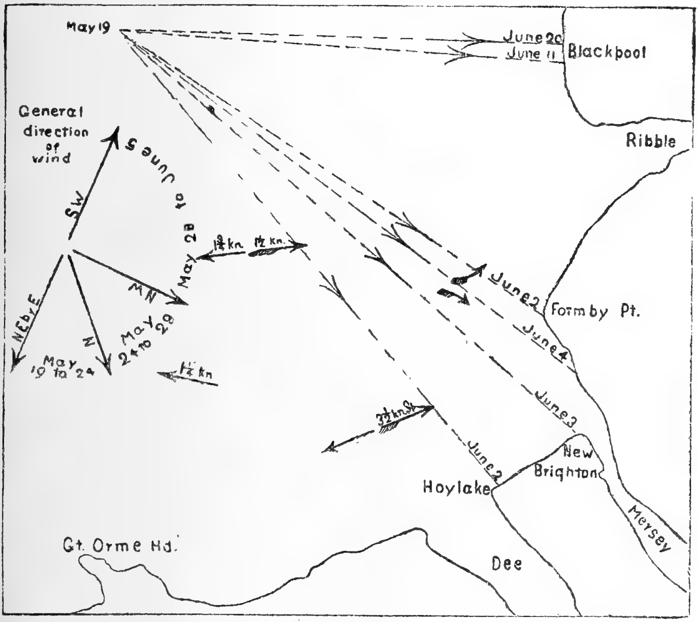


FIG. 3.—Apparent direction taken by six drift bottles, shewing directions of tidal streams and the general direction of the wind.

the later part of the period (June 5th—20th) the wind was very variable and light, and these bottles were probably carried up the coast towards Blackpool.

The results of this and former experiments seems to show that the destination of fish eggs spawned on the off-shore grounds either in the Lancashire or Welsh parts of the district will depend as much on the direction and force of the prevailing winds during the spawning period as on the general direction of the tidal streams. And since the prevailing winds during the early part of the year are from the W. and S.W., there will be a general drift to the northern part of the district, and to a lesser extent towards Liverpool Bay and the Ribble. The experiment made by Prof. Herdman seems to prove what was indeed conjectured by Mr. Ascroft, that the eggs from fish spawning off Carnarvon and Cardigan Bays might find their way into Lancashire waters. It might have been expected that many of these would go to the shallow waters in the above Bays, but this experiment shows that there is not sufficient in-draught into the bays from the deep water where we may, not unreasonably, look for spawning fishes, to produce this effect to any marked extent The area, therefore, over which it is necessary to trace the distribution of fish eggs and larvæ seems to be widened, and the experiments indicate the need for further investigations of the southern part of our extended sea-fisheries district.

Report on the Trawling Statistics collected by the "John Fell" and Sea-Fisheries Bailiffs.

By James Johnstone.

These trawling observations have now been continued for ten years, and it may be useful to indicate some conclusions of importance which may now be drawn from a detailed study of the whole series. It has already been pointed out that the great area of territorial waters which the Fisheries steamer and the bailiff's cutters have to traverse in the course of their police duties renders it impossible that any restricted fishing ground can be trawled on as often as might be desired. This applies more particularly to the off-shore fishing grounds, and it is only in the case of two in-shore grounds—the Blackpool Closed Ground and the Mersey Shrimping Grounds—that we possess fairly extensive series of observations. From the study of these it appears that some general conclusions regarding the abundance of fish on those areas during the last decade may now be made. It ought to be pointed out, however, that the observations referred to were not made with this precise object in view, but were intended rather as surveys of the fishing grounds, to supply evidence of the desirability of legislative restriction of methods and times of fishing, and from this latter point of view the series of observations made on the Mersey Shrimping Grounds is all that can reasonably be desired. But we will show, later on, that in order to ascertain the changes in the abundance of the different fishes frequenting the area from year to year, a more extensive and a differently planned series of observations than that we possess is necessary.

I. Discussion of the Statistics.

We have taken advantage, however, of the ten years series of observations to split up the whole period into two quinquennial parts, and to compare the average catches of immature fishes and shrimps during the first period (1893-7), with those of the second (1898-1902). It is hoped that by this treatment of the figures, irregularities due to conditions referred to later, are smoothed out, and that the data really represent the average condition of the grounds during the two five-yearly periods. The greater number of hauls have generally been made during the three months July, August and September, and as it is during those months that fish are most numerous on the grounds, they are the most convenient periods of the years to compare. But to confirm the results, the 4th quarters of the years, October-December, in the case of the Blackpool grounds, and the 2nd quarters, April-June, are also compared.

Blackpool Closed Grounds.

Average catches of immature fishes and shrimps made with a shrimp trawl during the 3rd and 4th quarters of the two quinquennial periods, 1893-7 and 1898-1902.

	No. of Hauls.	Soles.	Plaice.	Dabs.	Whiting.	Shrimps (Quarts).
3rd qr. 1893-7	7	26	1268	1932	259	2·5
3rd qr. 1898-1902	8	415	231	1316	296	4
4th qr. 1893-7	12	126	1017	5840	245	5
4th qr. 1898-1902	3	136	727	1049	125	4

The table shows that there has been a marked increase in the average of soles caught per haul during the period 1898-1902 over that caught during the earlier period 1893-1897. This increase is very apparent when the 3rd quarters of the years are compared, but it is also noticeable, though not so marked, in the average catches for the 4th quarters. The average catches of plaice and dabs, on the other hand, have undergone decided decreases during the same periods. Whiting and shrimps, as might have been expected, show no decided changes.

The same changes are to be observed in the figures dealing with the Mersey Shrimping Grounds, and here they are quite as marked, and being founded on a larger number of hauls than in the case of the Blackpool grounds, are probably a closer approximation to the real state of the fishery. The area considered is that known as the Deposit ground, and part of the Burbo Bank. It corresponds closely with the area which it was proposed to close against shrimp trawling during a certain part of the year.

Mersey Shrimping Grounds.

Average catches of shrimps and immature fishes made with a shrimp trawl during the 2nd and 3rd quarters of the two quinquennial periods, 1893-7 and 1898-1902.

	No. of Hauls.	Soles.	Plaice.	Dabs.	Whiting.	Shrimps.
2nd qr. 1893-7	49	17	274	392	157	8
2nd qr. 1898-1902	22	33	49	169	76	14
3rd qr. 1893-7	37	28	901	706	1136	15
3rd qr. 1898-1902	50	110	157	549	1242	14

It will be seen that the figures given above indicate for the Mersey grounds similar changes to those which have taken place further north. The conclusions for the two areas mutually confirm each other. Whatever part of the year be considered, the same marked increase of soles and decrease of plaice and dabs, and the same ambiguity of results with regard to whiting and shrimps is to be noticed. It would appear that we are really justified in concluding that there has been a marked increase in the number of young soles, and an equally marked decrease in the number of young plaice and dabs present on the Lancashire nursery grounds.

It is possible to regard the numbers of young fishes on these nurseries as dependent on the numbers of the same adult fishes on the off-shore grounds. That is, the more soles (say) present on the off-shore grounds and spawning there, the more young fishes will be found in the shallow water grounds, also, other things being equal, the number of adult soles on the off-shore grounds within the next two years may depend on the number of young fish on the nurseries. This is because the eggs and larvæ, resulting from spawning fish outside, drift in towards these shallow waters, and the young fishes settle there for a time. Then as they grow they move outwards to replenish the off-shore grounds. Perhaps it might be possible, if we thoroughly understood the whole matter, and possessed sufficient trawling observations, to forecast the approximate abundance of fish on the off-shore grounds one or two years ahead, from our knowledge of the abundance of young fish on the nurseries. At any rate, such considerations illustrate the importance of a thorough knowledge of these in-shore water fisheries and their changes.

II. On the Methods of Trawling Observations.

Any attempt to study closely the changes taking place in the fish population of an area by means of such a series of observations as we refer to above, discovers so many apparent irregularities that we are forced to conclude that only a very general conclusion can be drawn from such data, and then only when averages founded on considerable series are the values compared. It is very probable, for instance, that the five-yearly averages we have given above do indicate with some accuracy the condition of the Blackpool and Mersey grounds, but it is just as probable that any attempt to extract more than this from the observations, say the variation from year to year, is open to objection. If the averages of all the catches made in each year were compared with each other, errors would probably be made, for the abundance of fish in any place varies enormously from month to month during the year, and the hauls have not always been spread regularly over the year but are more numerous in the summer and spring of some years, and in the autumn of others. In comparing years with each other we are, therefore, compelled to compare only the catches made during the corresponding seasons, and in doing so we reduce considerably the number of hauls on which to calculate averages. Results based on only one haul per month or quarter are open to still greater objection than those deduced from small averages.

The exact conditions affecting the number of fish caught in a trawl net, employed for experimental purposes, are, therefore, worth considerable study and we do not know of any observations published* with this aim. The In-

* Except perhaps some observations made by McIntosh. See Report of the Royal Commission on Trawling; "On the effect of successive hauls on the same area," p. 374.

spectors of Fisheries have indeed made a laborious analysis† of the figures obtained by the trawling experiments of the Scottish Fishery Board, but this consists only of a statistical re-arrangement of the data; the actual conditions which might have influenced the catches were not studied, and it appears to us that one of the methods employed—that of reducing the total catches to numbers of fish caught per mile trawled over—is fallacious, and, when the small values dealt with are considered, likely to lead to error.

We have examined the results of the trawling observations made by our Fisheries steamer and by the bailiffs with the object of determining how far the catch is influenced by (1) the precise locality, (2) the tides, (3) the form and dimensions of the trawl net, and the method of using it. It is very generally believed by fishermen that all these conditions affect the catch, but in trawling observations it has been usual to consider large areas as being uniformly stocked with fish, and to regard the results of drags with trawl nets of the same length of beam, and of the same mesh, and employed for the same length of time, as comparable, and there seems little doubt that this assumption is unwarranted.

(1) *The Precise Locality.*

The fact that the distribution of fishes varies within close limits is brought out by many observations. On the 21st October of this year a series of hauls were made in Luce Bay* by the "John Fell." The object of these hauls was to obtain living mature plaice for the Piel Hatchery, and a series of short hauls, rather than one or two long ones were made. Each haul lasted for about an hour and a quarter, and about $2\frac{1}{2}$ miles were fished over. The net

† 16th Annual Report of the Inspectors of Fisheries for England and Wales, 1902.

* By permission of the Fishery Board for Scotland.

employed was a trawl with a 30-feet beam and with 7-inch meshes throughout. Trawling was continued all day from 7 a.m. to 5-30 p.m., and the meteorological conditions throughout were fairly constant. There was a fresh breeze from N.W. during the whole day. The sea was nearly smooth and the weather was fine. The barometer varied from 30·7 to 30·5, the air temperature from 9°C. to 11·6°C., and the surface temperature of the sea from 11·2°C. to 11·6°C. The results of the hauls are given in the following Table.

Results of 6 Hauls in Luce Bay on October 21st, 1902.

Description of the catch.	I. 7-0 a.m. to 8-15 a.m. $5\frac{1}{2}$ hrs. Ebb to $\frac{3}{4}$ Flood. Dragging partly against and with the stream.	II. 9-0 a.m. to 10-15 a.m. $1\frac{1}{2}$ hrs. Flood to $2\frac{3}{4}$ hrs. Ebb. Dragging with the stream.	III. 10-30 a.m. to 11-45 a.m 3 hrs. Flood to $4\frac{1}{4}$ hrs. Flood. Dragging with the stream.	IV. 12 noon to 1-15 p.m. $4\frac{1}{2}$ hrs. Flood to $5\frac{3}{4}$ hrs. Flood. Dragging with the stream.	V. 1-45 p.m. to 3 p.m. $\frac{1}{4}$ hr. Ebb to $1\frac{1}{2}$ hrs. Ebb. Dragging with the stream.	VI. 3-30 p.m. to 5-30 p.m. 2 hrs. Ebb to 4 hrs. Ebb. Dragging with the stream.
Plaice	14	157	17	136	123	347
Dabs	20	67	8	10	14	44
Turbot	—	1	—	—	—	—
Soles	—	—	—	1	1	1
Lemon Sole..	—	—	—	—	—	1
Skates	—	1	1	1	—	—
Rays	27	16	—	38	20	11
Totals	61	242	26	186	158	404

The area trawled over is shown in the accompanying sketch chart, where the positions, directions and lengths of the six hauls are marked. It will be seen that they are restricted to a narrow strip round the west and north sides of the bay. The depth was very uniform, 4 to 6 fathoms, and the bottom everywhere consisted of sand. The area was, in fact, a limited one, where the physical conditions were everywhere constant, and where, if those conditions determined the distribution of the fish, one would have expected a similarity of result in the hauls made. These, however, show the most remarkable differences. Haul 6 may be left out of consideration as it was longer than Nos. 1 to 5, but in those five hauls the number of plaice caught varies from 14 to 157, of dabs from 8 to 67, and of ray from 0 to 38. The only variable condition is the state of the tide, and there are no apparent regularities

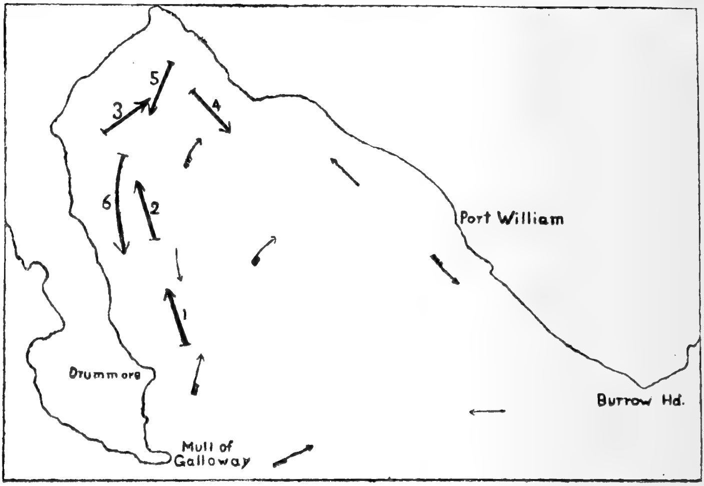


FIG. 4.—Luce Bay, shewing the positions, approximate directions and lengths of the drags.

to be seen by comparing the catch with this condition. There is no doubt, of course, that the state of the tide did affect the number of fish caught, but the variation in the catches due to this cause is apparently disturbed by variations due to the irregular distribution of the fish on the bottom.

The same results are given by hauls made by a shrimp trawl on the Mersey grounds. The following table gives the result of four hauls made by the same boat during the same day on a very limited area—the deposit ground. The hauls were made immediately after each other, and the length of ground trawled over varies slightly, but in an insufficient degree to account for the difference in the catches.

Four hauls made on the Mersey Deposit ground on February 16th, 1894.

	I. $\frac{1}{2}$ hr. ebb; 2 miles long.	II. 3 hrs. ebb; $1\frac{3}{4}$ miles long.	III. $4\frac{3}{4}$ hrs. ebb; 2 miles long.	IV. Low water; $1\frac{1}{2}$ miles long.
Soles	6	14	0	0
Plaice	221	150	44	284
Dabs	120	383	210	33
Whiting	101	131	34	0
Shrimps (in quarts) ...	7	$4\frac{1}{2}$	2	$2\frac{1}{2}$

Hauls made on the same day, by the same vessel and net, for the same time and over the same length on the Blackpool closed grounds, have given equally dissimilar results.

Two hauls on the Blackpool closed ground on January 13th, 1902.

	I. High water; $1\frac{1}{2}$ miles; 1 hour.	II. 2 hours ebb; $1\frac{1}{2}$ miles; 1 hour.
Shrimps	15 quarts.	4 quarts.
Plaice	340	394
Dabs	10,900	24,300
Whiting	400	540
Codling.........................	100	270
Herring	156	90

These instances illustrate the contention that hauls made on the same limited area and on the same day under conditions as nearly as possible alike do not necessarily give similar results. This applies with particular force to hauls made with small apparatus and for a short time. As might be expected, hauls made on the same area with large nets and extending over a considerable distance give results which are much more similar than in the cases given above. Three hauls witnessed by Dr. Fulton* illustrate this. They were made by a commercial trawler working in the Moray Firth on September 3rd, 1900, and using an otter trawl with a head line measuring 120 feet.

The results were, for the more important fishes:—

	I. 1-45 a.m. to 6-45 a.m.	II. 7-40 a.m. to 12-40 p.m.	III. 1-20 p.m. to 6-30 p.m.
Cod	49	34	71
Haddock	1640	2407	2202
Whiting	92	52	291
Witches	119	92	7
Long rough Dabs	68	35	49
Sail-Flukes	12	8	3

Here the catches are more similar, though in the case of some of the fishes there is a considerable difference between the numbers caught. But it is obvious that a longer haul and with a larger net, must, by merely covering a greater area, tend to eliminate lesser inequalities of distribution.

(2) *The Effect of The State of Tide.*

This is difficult to study since a suitable experiment would necessitate trawling over the same line at least half-a-dozen times a day for a fortnight, and during that time considerable changes in the density of the fish might occur. But such an experiment repeated several times

* 19th Rep. Scottish Fish. Board, 1901, p. 67.

would, no doubt, give much information. In the absence of data of such a kind we have made a study of the statistics collected on the Mersey grounds by Captain Eccles, during the last ten years. It has been stated that these observations had an entirely different aim, and they are, therefore, not always suitable for the elucidation of our point. They do give some results, however, which are all the more reliable since they are in general agreement with Captain Eccles' personal experience of the grounds. It is first to be noted that there is a very distinct difference between catches made during spring tides and those made during neaps. All the catches made during the months of July, August, and September, with tides of from 17 to 20 feet, have been collected and their average compared with that of those made during the same months with tides of from 11 to 14 feet. The results are given below.

Average catches of shrimps and immature fishes on the Deposit grounds during August-September, 1893-1902.

	No. of Drags.	Soles.	Plaice.	Dabs.	Whiting.	Shrimps (Quarts).	
SPRINGS	8	48	588	840	1385	17	JULY.
NEAPS	7	22	343	608	2310	16	
SPRINGS	13	100	358	868	1168	14	AUG.
NEAPS	10	59	170	588	1670	14	
SPRINGS	10	81	789	655	846	16	SEP.
NEAPS	6	21	199	965	1301	11	

There is little doubt that more soles and plaice are caught during spring than at neap tides. The same is the case with dabs for two of the months considered, while whiting seem to have been more abundant during neaps than during springs, but the distribution of this fish is in other respects very capricious, and too much stress must not be laid on the above figures. Shrimps do not seem to be so much affected. Captain Eccles informs us, however, that in his experience more shrimps are generally caught at springs than at neaps, on account of the greater muddiness of the water during the higher tides.

As regards the influence of the state of the tide as to ebb and flow on the numbers of fish caught, much remains to be made out. We have collected the hauls made during every hour of the tide for the months July, August, September, and calculated the average catches. The data are rather incomplete, too few hauls having been made just before high water to give satisfactory averages. The results are set out in the table and on the accompanying chart where the abscissæ represent part of one daily tidal cycle and the ordinates the average numbers of fishes caught.

Average catches of fish and shrimps made with a shrimp trawl on the Mersey grounds during July, August, September of the years 1893-1902. Arranged for each hour of the tide.

State of Tide.	No. of Hauls.	Soles.	Plaice.	Dabs.	Whiting.	Shrimps (Quarts).
H.W. to one hour ebb ...	4	140·7	848	421	2168	20
1 to 2 hours ebb...........	10	57	167	412	1165	11
2 to 3 hours ebb...........	14	46	339	650	1755	16
3 to 4 hours ebb...........	10	50	329	776	1590	14
4 to 5 hours ebb...........	13	95	307	530	991	15
5 hours ebb to L.W.........	2	288	130	1688	1527	22
L.W. to 1 hour flood...	10	46	319	645	1102	19
1 to 2 hours flood	7	82	445	491	677	14
2 to 3 hours flood	3	102	679	844	2474	9

Whiting are again seen to vary in an irregular manner but it seems certain that more soles and dabs are got about low water, and that more plaice are got about high water. Captain Eccles informs us that this is his experience as regards soles, dabs and whiting, and that

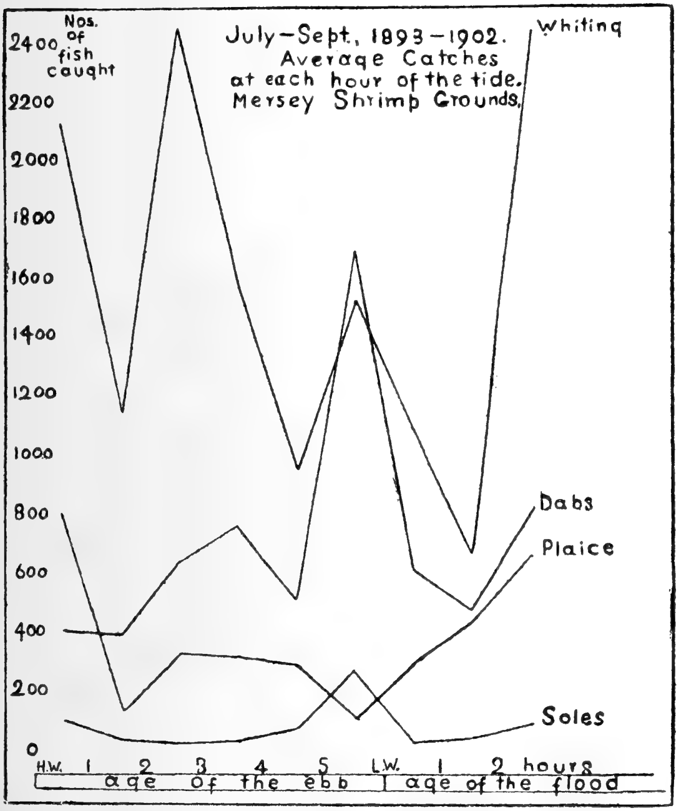


FIG. 5.—Average catches of immature fishes in relation to the state of the tide.

often plaice behave as the curve shows but not invariably so. It is evident that a large number of carefully devised observations are required to make out these variations in a satisfactory manner, and it also appears probable that the same variations will not necessarily be found in different places. There is no doubt that this cause has some effect in producing the marked differences in the catches from the same area on the same day, but it alone is not enough to account for all.

(3) *Form, etc., of the Net and the Method of Use.*

It is obvious that with small nets, sweeping a small area and catching few fish, the exact form and dimensions of the apparatus must remain constant so that similar samples will always be taken. But nets are frequently lost or get damaged, and on every such occasion the exact trim of the apparatus may alter and its catching power may change. The trawl net used for scientific observations is really a physical instrument, but it has apparently never been regarded in this way, and the "constants" for any particular apparatus determined. We do not know of any experiments, except those of Mr. Dawson on the catching power of the net in relation to the size of the mesh, on the differences in catching power that alterations in the length of the net, the beam, the foot rope, etc., will make, although it is quite evident that for the purposes of scientific trawling these should be known. Fishermen know that apparently slight differences in the trim of the net, the length and weight of the foot rope, or the amount of "grip" given to the latter, for instance, may make differences in the catching power of the net. So also the exact method of using it. Two fishermen using the same vessel and net and on a ground on which fish may be reasonably supposed to be uniformly distributed will not necessarily get the same catches. It follows that in the collection of any considerable series of observations from which detailed conclusions are to be drawn, these considerations must be borne in mind, as it must often happen that the observations are made by different people and with constantly changing nets. In a reliable series of observations the length and duration of the drags would be always the same. To compare drags of varying lengths after correcting them for the length of the haul, as is done by the Inspectors of Fisheries in the paper already referred to, appears to us to be fallacious. For the amount of fish caught by a trawl net is apparently not proportional to the distance trawled over. That is, during a 3-hours drag over a uniform ground one third of the catch will not be made during the last hour, for as the net becomes filled with fish and other material its catching power diminishes. This is because the weight of material in the cod end may, with a certain construction of net, tend to cause the irons and foot rope to bear less heavily on the ground, perhaps to become lifted altogether. And the more full the net becomes the less water will pass through its meshes, and some kinds of fish entering the mouth will have much better chances of escaping.

In an ideal series of trawling observations the figures obtained would represent the varying density of fish on the bottom on the areas considered, and would represent this only. But we have seen that the catch made may be influenced by many causes such as the daily and fortnightly state of the tide, and the constants of the apparatus employed, and these may vary quite independently of any variation in the density of the fish. To correct the observations for these varying conditions, such as would be done in a quantitative physical experiment, is, in the present state of our knowledge of the matter, quite impossible. And the distribution of the fishes on the bottom is probably much more variable than is generally supposed, so that to obtain results which would apply to even a moderately large area, 100 square miles, for instance, would necessitate a number of hauls being made. It has been generally supposed that on an area where the physical conditions, depth of water, and nature of bottom, are similar, the distribution of fish is pretty uniform. The distribution of fishes will depend primarily on the distribution of their food, and how variable this may be will be seen by taking any area of cockle-bearing sands, ten miles by ten miles, and observing how irregularly cockle beds may be distributed over this area, though the physical conditions are closely similar in every part.

It will appear, then, that to obtain results which will give more than merely general conclusions, such as we have given with regard to the Blackpool and Mersey grounds, must require very frequent trawling observations and the employment of averages based on rather large series of figures. By considering averages only and calculating these from many data, some of the possible errors which we have indicated above as inseparable from isolated observations, might be eliminated.

Such considerations as we have dealt with above appear, then, to indicate that if a series of trawling observations is to be undertaken with the view of determining the changes in time in the fish population of a fishing ground, these things must be borne in mind:—

(1) The nets employed must be chosen and used so that their fishing power will be equal—unless one net is employed throughout the series of observations.

(2) Due regard must be paid to the differences which the varying states of the tide must make in the catches, or the observations must be made under the same conditions of tide.

(3) Finally, the results should be based on the averages of several observations taken at neighbouring places so that the differences due to irregular distribution in space may be as far as possible eliminated.

Table for the determination of Pelagic Fish Eggs.

By Heincke and Ehrenbaum.

(Translated by J. Johnstone.)

The following Table is translated from that given by Heincke and Ehrenbaum in the Kiel Kommission Report* for 1900. It refers to the species found in the German part of the North Sea, but will most probably apply to many of those inhabiting the Irish Sea as well. †

In some cases the determination of the species is uncertain. These are indicated in the table (*i.e.*, "*Trigla* sp.," where no attempt is made to distinguish the various species).

The eggs of the species marked with an asterisk are as yet imperfectly known. The Roman numerals indicate the months during which the fishes spawn. The authors claim that the table is useful chiefly as the means of a first determination of the eggs, and more detailed information as to special characters is given in the systematic part of their paper.

* "Die Bestimmung der schwimmenden Fischeir und die Methodik der Eimessungen. Wiss. Meeresuntersuch. N. F. Bd. 3. Abth. Helgoland, Heft 2, p. 294, 1900.

† Certain other species, of economic importance in our district, are not included in this Table. These are :—*Labrax lupus* (Bass), *Merluccius vulgaris* (Hake), *Molva vulgaris* (Ling), *Lepidorhombus megastoma* (Megrim), *Mugil chelo* (Lesser grey mullet), and *Hippoglossus vulgaris* (the Halibut). The main characters of the eggs of some of these species are known but others still require investigation.

TABLE.

A. Eggs with Oil.

I. Oil in numerous small globules.

A. Oil globules colourless.

1. Gathered together in groups of innumerable very small globules. Egg diameter 1·10—1·38 mm. IV.—VIII. ... *Solea vulgaris.*

2. Single and scattered fairly regularly over the yolk.

a. Yolk superficially segmented. Egg dia. 0·69—0·94 mm. Pigment clear yellow. V.—VIII. ... ... *Solea lutea.*

b. Yolk unsegmented. Egg dia. 0·66—0·98 mm. I.—VIII. *Motella* sp.

B. Oil globules chrome yellow, scattered singly over the yolk. Becoming smaller during development. Egg dia. 1·01—1·13 mm. VI.—IX. ... ... *Trachinus* sp.*

II. Oil mostly in the form of a large oil globule. Sometimes with one larger and several smaller globules.

A. Yolk segmented.

1. Segmentation total. Egg dia. 0·81—1·04 mm. VI.—VIII. *Caranx trachurus* *

2. Segmentation restricted to a marginal zone. Egg dia. 0·82—0·91 mm. VI. ... ... *Mullus surmuletus.**

B. Yolk unsegmented.

1. Very small eggs, 0·60—0·98 mm.
   - *a.* Egg extremely small, 0·6—0·76 mm., pigment rust-red, anus immediately behind yolk sac. VI.—VIII. ... *Arnoglossus* sp.
   - *b.* Egg larger, 0·66—0·98 mm. Oil occasionally pigmented. Pigment black, anus not formed. I.—VIII. *Motella* sp.

2. Medium-sized eggs 0·72—1·10 mm.
   - *a.* Oil globule large, about 0·3 mm. dia., often pigmented, egg dia. 1·0—1·1 mm. Pigment green-yellow and black, anus not formed. III.—VI. ... ... *Lota molva.**
   - *b.* Oil globule small, 0·09—0·19 mm. dia.
     - ‡ Oil globule very small, 0·09—0·16 mm. dia. Pigment delicate clear yellow and black, dotted, egg dia. 0·72—0·91 mm., anus immediately behind yolk sac. IV.—VIII. ... ... *Rhombus norvegicus* (?)
     - ‡‡ Oil globule larger, 0·14—0·19 mm. dia. Egg dia. 0·75—0·91 mm. Pigment chrome-yellow and black, anus not formed. V.—IX.... ... ... *Raniceps raninus.*

3. Large eggs, 0·91—1·54 mm. dia.
   - *a.* Oil globule large, about 0·28 mm. Egg dia. 0·97—1·38 mm. Pigment black, and later on, moss-green. V.—VIII. ... ... *Scomber scomber.*

b Oil globule large to medium, 0·35—0·19 mm., occasionally pigmented. Egg dia. 1·10—1·54 mm. Pigment bright yellow and black. Rudiments of pectoral fins early visible. IV.—IX. ... ... *Trigla* sp.

c. Oil globule relatively small.

‡ Oil globule 0·14—0·22 mm. dia. Egg dia. 0·91—1·195 mm. Pigment black and red-brown. IV.—VIII. ... ... *Rhombus maximus.*

‡‡ Oil globule 0·21—0·25 mm. dia. Egg dia. 1·24—1·50 mm. Pigment black and intensely orange yellow. III.—VIII. ... ... *Rhombus lævis.**

B. Eggs without Oil.

I. Perivitelline space very large. Egg dia. very great and variable, 1·4—2·6 mm. Pigment yellow and black. I.—V. ... ... *Drepanopsetta platessoides*

II. Perivitelline space not large.

A. Egg capsule with polygonally arranged ridges. Yolk superficially segmented. Pigment predominatingly yellow.

1. Distance apart of polygonal ridges 0·03—0·06 mm. Egg dia. 0·69—0·94 mm. IV.—VIII. ... ... *Callionymus lyra.*

2. Distance apart of polygonal markings 0·01—0·02 mm. Egg dia. 0·66—0·79 mm. VI.—VIII. ... ... *Callionymus maculatus.**

B. Egg capsule without polygonal ridges.

1. Yolk completely segmented. Anus lies far behind.

   a. Egg oval in form, dia. about 1·2—0·7 mm. VI.—VII. *Engraulis encrasicholus.**

   b. Egg round in form, dia. 0·82—1·23 mm. Pigment arranged in delicate black dots. III.—VIII ... ... *Clupea sprattus.*

2. Yolk not segmented. Anus does not lie far behind.

   a. Egg dia. great 1·16—2·11 mm.

   ‡ Pigment yellow and black. Anus immediately behind the yolk sac.

   * Egg dia. 1·63—2·11. I.—V. ... ... *Pleuronectes platessa.*

   ** Egg dia. 1·19—1·45. IV.—IX. ... ... *Pleuronectes microcephalus.*

   ‡‡ Pigment black. Anus not formed.

   * Egg dia. 1·26—1·67 mm. Pigment in older embryos in double lines on the under side of the tail. I.—VI. ... ... *Gadus æglefinus.*

   ** Egg dia. 1·16—1·60 mm. Pigment in older embryos in four transverse zones. I.—VI.... *Gadus morrhua.*

   b. Egg dia. medium, 0·90—1·32 mm.

   ‡ Pigment yellow and black.

   * Pigment appearing late, very black and approaching to yellow. Egg dia. 1·07—1·25 mm. Anus immediately behind the yolk sac. V.—VIII. ... ... *Pleuronectes cynoglossus.**

** Both pigments equally brightly developed. Egg dia. 1·01—1·32 mm. Anus not formed. I.—VII. ... ... *Gadus merlangus.*

*** Black pigment predominant. Yellow developed late and only on the fins. Egg dia. 0·90—1·15 mm. Anus not formed. IV.—VIII. ... *Gadus luscus.**

‡‡ Only black pigment present. Anus not formed.

* Pigment irregularly distributed. Egg dia. 1·03—1·19 mm. I.—V. ... ... *Gadus virens*

** Pigment like that of *Gadus æglefinus* in a longitudinal line on the tail. Egg dia. 1·10—1·30 mm. III.—V. ... ... *Gadus pollachius.*

C. Egg dia. small, 0·69—1·10 mm.

‡ Pigment yellow and black. Anus immediately behind the yolk sac.

* Pigment bright. Egg dia. 0·82—1·10 mm. I.—VI. ... ... *Pleuronectes flesus.*

** Pigment pale. Egg dia. 0·69—0·98 mm. I.—VII. ... ... *Pleuronectes limanda.*

‡‡ Delicate black pigment. Anus is a streak behind the yolk sac. Egg dia. 0·72—0·94 mm. V.—VIII. ... ... *Ctenolabrus rupestris.*

Technical Instruction in Sea-Fisheries Science.

(A Memorandum prepared for the use of the Committee).

By W. A. Herdman.

At a Meeting of the Scientific Sub-Committee, held at Preston on November 18th, 1902, I was requested to draw up for circulation a statement as to the educational use that has been made of the Lancashire Sea-Fisheries Laboratory and Hatchery at Piel, and as to any further developments that are desirable in teaching the application of science to fishery problems either to fishermen or to others.

I think it well to distinguish between three classes to whom instruction may be given, viz.:—(A) fishermen, (B) technical students, and (C) the general public.

A.—*Practical Classes for Fishermen.*

We have found in Lancashire that lectures alone, even if well illustrated by lantern slides and accompanied by the exhibition of specimens and of objects seen through the microscope, produced very little effect upon the average fisherman. It was not until, after trying various forms of lectures and demonstrations, we started actual laboratory work for fishermen at Liverpool three years ago (February, 1900), that the results proved satisfactory. After a few days actual practical work with their own hands the men became keen and enthusiastic, they welcomed the new information, trusted their microscopes and believed what they saw; they thoroughly appreciated the importance of what they found out, and were evidently anxious for further information.

During the last three years seven practical classes have been held. The first two were in the Fisheries laboratory and in the Zoology Museum at University College, Liverpool, in February and March, 1900. The next three were at the Piel Hatchery in March, April and July, 1901, and the remaining two were also held at Piel during last April and May.

I have no hesitation in recommending that in future the classes be held at Piel. There are facilities in the provision of fresh material, especially living surface organisms from the sea, and in the study of the stages in fish hatching, that can be given better at Piel than anywhere else.

For several reasons the classes must be held in spring. During March and April is the most convenient time for the fishermen themselves, it is the best time for obtaining the necessary material from the sea, and it is the only time when the fish hatching can be studied.

Each class lasts for two weeks, and it is found that two hours in the forenoon followed by two hours in the afternoon, of continuous laboratory work is as much as the fishermen can manage without strain, in each day.

Ten men form a convenient number to teach at one time, but we can accommodate fifteen, and classes of that number have been held at Piel. On one occasion at Liverpool we had sixteen in the class.

The fishermen can be accommodated in lodgings at Roa Island during the fortnight, and the allowance paid to each man selected for a class is £5 to meet his travelling, living and any other expenses. This money has been provided by the Technical Instruction Committee, and with each £100 for the men £20 has been given to defray the expenses of furniture, fittings and material for the class. No part of the grant made by the Technical Instruction Committee has in any case gone to the teachers.

The work of teaching the classes at Piel has been in the hands of Mr. James Johnstone, B.Sc., from the Liverpool laboratory, but he has been assisted when necessary by Mr. Andrew Scott, so that both of these gentlemen have taken part in the work.

The course of instruction includes:—

1. Actual observations (microscopic and otherwise) on the structure and mode of reproduction of the common sea-fishes, mollusca and crustacea; on the food of fishes and the microscopic life in the sea; on the varieties and nature of fish and shell-fish spawn; on the life-histories and habits of the edible fishes and shell-fish and many other similar matters. All the above is given in the form of practical laboratory work, the preparations being made and examined by the fishermen themselves. The material dealt with is fresh from the sea or shore, and in the case of the microscopic fish food, eggs and embryos are brought in and examined alive.
2. Short demonstration on some of the above matters by the teachers.
3. Occasional short lectures with lantern slides in order to recall, illustrate and revise past work.
4. Demonstrations on how best to secure and fertilise ripe eggs from spawning fish when brought up in the trawl.

As to further developments of the system, not much more is possible with our present accommodation and staff than we are now doing. Classes might be held from near the end of February till early in May. This is apparently the only time of the year that suits the fishermen, and it is also the time when the hatching work is going on and most of the economic marine animals are spawning. Four classes at most could be held during that time, and each class might consist of 15 men, so that 60 in all could be dealt with during the year. That seems to be the maximum possible without going to very considerable additional expense. The cost for the 60 men, at the present rate, would be £300 to pay the travelling and lodging expenses, and £60 for the class expenses. More substantial work-tables, some additional microscopes and other accessories are also required.

B.—*Technical Students.*

In addition to the fishermen's classes occasional demonstrations have been given to parties of men who have visited Piel under the auspices of the Furness Rural District Technical Instruction Committee. Several school teachers from Barrow have also visited the laboratory for purposes of instruction and occasionally advanced students have been sent from Liverpool. Finally there have been from time to time, generally in the long vacation, scientific men from Liverpool, Manchester and elsewhere, who have taken advantage of the facilities we offer for purposes of original research.

A few years ago a scheme was proposed and passed by the Technical Instruction Committee and the County Council whereby two £60 Fisheries Science Scholarships were made tenable partly at University College, Liverpool, and partly at Piel. During the first year only one applicant appeared and he failed to pass a satisfactory preliminary examination, and then, unfortunately, the scholarships were allowed to lapse. It cannot be considered that the scheme was given a fair trial, and I hope that it may still be put into operation.

These Scholarships should be held by men who are studying fisheries science with a view to becoming experts; but in addition to these there are many other students to whom even a short course of study at Piel would be very advantageous. I would especially instance those who propose to be school teachers—whether of science subjects or not—to all such a knowledge of even the elementary facts and principles of Biology is of very great value. I would suggest that some of the Technical Instruction Committees of our County Boroughs might establish small scholarships, say of £10 each, to enable the holders to enjoy a course of instruction at the Piel laboratory during some vacation.

Possibly, also, more definitely organised classes in connection with the Barrow Technical School might be arranged.

C.—*The General Public.*

A certain amount of useful teaching work might be carried out in connection with our travelling Fisheries Exhibition. Our cases of specimens have now visited half-a-dozen of the chief towns of Lancashire (Liverpool, Salford, Preston, Bolton, St. Helens, Liverpool again, Piel and Barrow), have been exhibited to the public in museums or free libraries for from three to six months at a time, and have been, I believe, on every occasion much appreciated. While at Salford the Exhibition was visited by over 120,000 people. In the past a charge of £15 has been made by the Sea-Fisheries Committee to each institution in order to defray the expenses of packing, travelling, renewals and repairs. I believe that charge has deterred some of the smaller towns from applying for the exhibition. If the necessary expenses could be met in some other way, such as by a grant from the Technical Instruction Committee, I feel sure that it would be useful to send the exhibit to many of our smaller coast towns.

Furthermore, I should like to see it arranged that one of our assistants, such as Mr. Johnstone, should be engaged to visit the exhibition occasionally, say once a week, and give from the specimens in the cases short lectures or demonstrations open to the general public.

This would not only spread a knowledge of some of the more elementary facts in regard to marine life amongst our maritime population, but it would also be calculated to explain and arouse an interest in the work of the Sea-Fisheries Committee, and remove any misunderstanding and prejudice that may possibly exist.

L.M.B.C. MEMOIRS.

No. X. PATELLA.

BY

Professor J. R. Ainsworth Davis,

AND

H. J. Fleure, B.Sc.

Contents.

Preface.

The chief objects of this Memoir are:—

(1) To provide a reliable account of the anatomy of *Patella vulgata*.

(2) To treat the subject matter so as to show the place among Gastropods which this type occupies.

The work has been carried out in the Zoological Laboratory of the University College of Wales; and no facts are included that we have been unable to personally verify, except those of the short résumé we have given from Patten with regard to the development.

It is unnecessary to refer to the many authors whose works we have had to consult, but we wish to acknowledge our special indebtedness to the researches and theories of Ray Lankester, J. W. Spengel, Pelseneer, Rémy Perrier, Bela Haller, Lacaze Duthiers, Boutan, Grobben, and Patten.

The matter which we believe to be new includes the following chief points:—

(1) A lateral glandular streak has been found along each side of the foot of young specimens, resembling that found in *Nacella* and its allies.

(2) A muscular zone (which we name the internal pallial muscle) has been found extending in the mantle between the tips of the shell muscle.

(3) The structure of the Crop, and inferences drawn therefrom as to special torsion of the viscera of Docoglossa during consolidation of the visceral hump.

(4) The respiratory function of the nuchal cavity as regards damp air.

(5) Discussion of the evolution of the present topographical relations of rectum, kidneys, pericardium, and heart.

(6) Details of mantle innervation and pallial tentacles.

Our best thanks are due to Professor W. A. Herdman, D.Sc., F.R.S., the Editor of this series, for his general advice and special suggestions, and to Prof. J. Travis Jenkins, D.Sc., Ph.D., late of Aberystwyth, for working out several intricate details of mantle innervation as well as other points. The greater number of the drawings are original, but a few are based on those given in Lankester's article "Mollusca," in the Encyclopædia Britannica (9th edition), and those of the development are after Patten.

THE COMMON LIMPET (*Patella vulgata*).

General Description.

The Limpet belongs to the asymmetrical class of Mollusca (*Gastropoda*), and, though it has lost both ctenidia, is referred to the order Prosobranchia, the members of which have the ctenidium (or ctenidia) anterior to the heart. Among the Prosobranchia its place is in the group of Docoglossa, while the absence of ctenidia and presence of a compensating circlet of pallial gills show that it belongs to the sub-group Cyclobranchiata.

Limpet shells are so simple and their few characters are so subject to variation, that it is not easy to classify the British forms into varieties and species. Of these, however, two are generally recognised:—

P. vulgata has its shell substance greyish or yellowish, but never white. The margin is fairly simple, and, though the radiating ribs vary a good deal, they are not usually very strongly developed. Aged shells have their vertices more central than those of young ones.

P. athletica has its shell substance white, and possesses numerous elevated ribs with regular series of projecting scales, the interstices being stained with brown. The shell is usually depressed. Forbes and Hanley state that Clark found the pallial tentacles shorter and thicker and the pallial gills longer than in *P. vulgata*. This species is fairly abundant but is locally distributed. It is usually found far down the intertidal zone, and its flesh is said to be tougher than *P. vulgata*. Jeffreys considers *P. athletica* to be merely a variety, and he enumerates three other varieties:—*P. elevata*—small, round, high; *P. picta*—small, thin, alternate ribs reddish and dark blue; *P. intermedia*—smaller, flatter, and oval, finer ribs, orange crown, inside of shell golden yellow or flesh-tint, fine ribs towards edges.

HABITAT.—*Patella* inhabits the intertidal zone, affixing itself to rocks with such force that it is dislodged only with some difficulty. The method of this adhesion is not known with absolute certainty. Limpets will hold on very tenaciously to a surface smaller than the foot, so it seems improbable that the latter acts like a sucker as has been suggested. Another view is that the animal is fixed to the rock by means of a glutinous substance secreted by its foot, but, from examination of specimens allowed to fix themselves to plate glass, it seems that this idea is also ill-founded. The most plausible explanation, and the one supported by our evidence, is that it is a case of adhesion of two very closely apposed surfaces, the foot being, so to speak, rolled out on the rock.

When the young limpet finds a suitable spot, it makes a home of it, returning thither even after wandering some distance in search of food. This "homing" faculty, noted by observers since the days of Aristotle, is one of the most remarkable endowments of the limpet, and it will be referred to further on, when the sense organs are described. One of us has studied this matter by observing animals, specially marked with enamel paint, which were moved and watched at suitable intervals.

As a result of continued residence on one spot an oval depression is formed in the rock-surface, at any rate on the softer and smoother rocks. This is called the limpet's scar. It has been suggested that the scar is made by the chemical action of an acid secretion of the foot, but there is no proof that any such secretion is produced, and well-marked scars are formed upon siliceous rocks. The distinctness of the scar appears to vary inversely as the hardness of the rocks, and its peripheral portion is deepest. Probably the excavation results from the mechanical action of the foot surface and of the bevelled edge of the shell. During life the animal constantly leaves and returns to its home, and even the comparatively soft foot must, therefore, bring about an appreciable amount of wear, especially as fixation is usually preceded by a certain amount of shuffling or twisting round on the scar. The deeper margin of the scar clearly indicates shell action.

An allied form, *Helcion pellucidum*, found at the top of the Laminarian zone, lives, when adult, in a sheltered "home" excavated in the bulb or, more rarely, in the frond of Laminaria, and possesses the same faculty of returning thereto after excursions. The depressions in the Laminaria surface are deeply eaten out, and have tracks leading from them. The shell is thinner than that of *Patella*.

Food and Enemies.—The chief food of limpets consists of the minute Algæ covering the rocks, but they also eat the larger forms *Corallina*, *Melobesia*, *Fucus*, and *Laminaria*. With this food they must also take in a number of minute animals. The details of the feeding process are discussed later, in the description of the alimentary canal. They feed, at least partly, while the tide is low, returning to their scars with its advance to avoid danger from the tidal wash, but it seems likely that they also feed a good deal when covered by water; some, indeed, have actually been watched doing so, and, moreover, the finest limpets are often found low down on the shore where their uncovered period is necessarily very limited. Aquarium specimens also can be kept submerged for weeks, apparently without ill effect. On the other hand, tiny limpets and feeble scars occur in abundance high up the shore. The rock barnacles (Balanus) compete with the limpets for space, and in this, perhaps, lies the need of the development of the homing faculty, since a smooth surface is required for fixation. Limpets cannot, moreover, successfully invade an area already occupied by these competitors. Fixation is a protective measure against the wash of the tide and the attacks of enemies, and the normal adhesion can be largely increased when the shell is touched.

The limpet, with these habits, does not seem to have much to fear from active enemies when once the manifold dangers of youth are past; but it is to some extent eaten by seabirds, by the common starfish, and even by rats, while man is, in some districts, a serious enemy.

External Characters.

I. Shell.—The shell is conical and its base has an elliptical outline, the anteroposterior diameter being greater than the transverse. The apex of the cone is in the sagittal plane and nearer the front end; its exact form varies greatly, being sometimes, especially in young limpets, bent over and pointing forwards. The external markings of the shell vary remarkably within the limits of the species, but there are always some lines radiating from the apex and other lines concentric about that point. The former are raised ribs running to the shell margin, but they vary considerably in number and in prominence; the latter are lines of growth. The edge of the shell is notched proportionately to the prominence of the radiating ribs, and its rim is roughly chisel-shaped, with the bevelled edge inside, and forming an efficient instrument for enlarging the scar and deepening its margin. There is considerable variation in the general shape of limpet shells, those of animals living far up the shore and on exposed flat surfaces being typically low and broad, while those of animals living nearer the low tide limits and in sheltered positions are often high and narrow, but these rules are not without exceptions. Plate I., fig. 1, shows extreme types of shell.

The larval shell shows the beginning of a spiral. This shell grows chiefly by additions to its posterior border and its mouth is thus lengthened and broadened until it has a cap-shape with the apex (the remains of the spiral) far forwards. This apex then breaks off and the hole is closed by secretion of nacreous material on the inside. In further growth the anterior border seems to have a larger share and older shells thus usually have the apex further back than young ones. This, however, depends largely on the precise form of the shell, the broad low cones above mentioned having the apex further back than the tall narrow ones. The transition from spiral to conical shell, with the correlated consolidation of the visceral hump and the broadening of the foot into an oval adhesive sole, are all adaptations to this animal's special mode of life. Limpets are peculiarly exposed to the wash of the tide and of storms, and it is an advantage to them to be able to adhere firmly to the rock and present as small an area as possible to the waves. Hence the thick, plate-like foot and the preparation of a smooth surface to which it can effectively cling. The shape of the shell offers a minimum amount of resistance to waves and tide; at the same time the shell is an effective protection against enemies, for it can be pulled down so as to completely cover the animal, while the deep margin of the scar increases the difficulty of detachment. The peripheral position of the shell-muscle, and its symmetrical disposition are adaptations to this protective arrangement.

The spiral-shelled Gastropods protect themselves by retreating far into the shell, the part of the animal nearest the opening being further protected in many cases by an operculum. When thus retracted, the animal can be knocked about without incurring serious risks. This form of protection is suited to an actively creeping animal. In a cap-shelled form the power of retraction is much less and the operculum has gone, so the animal draws down its cap and remains tightly affixed to the spot until the danger has passed.

Internally the shell shows markings, of which the most conspicuous is the horse-shoe shaped impression, with expanded front ends, of the shell muscle. This impression is divided into partially distinct areas corresponding to the component bundles or fasciculi making up this muscle. On the outer side of the horse-shoe muscle we see the pallial impression which is continuous across the front of the shell.

Sections of the shell show its structure to be as follows (Plate I., fig. 2):—

A.—A thin irregular external layer of brownish colour.

B.—A middle layer made up of very compact crystalline material the external part of which (*a*) is penetrated in every direction by branching minute canals while its inner part (*b*) is comparatively clear.

C.—An internal layer made up of numerous smaller layers extending for varying distances. Each such layer is, in its turn, made up of parallel but obliquely arranged lamellæ. This portion is thickest under the dome. It is the nacreous or pearly layer.

Accounts of the shell structure have been given by Gibson and by Boutan. Gibson noted the minute branching canals in the external part of the shell and ventured to suggest that they were due to boring Algæ, which our observations make us think highly probable, Boutan speaks of an intermediate layer between the middle and internal, but, unless this corresponds with the inner and clearer portion (B, *b*) spoken of above, we have not found it.

II. Soft Parts of Exterior.—Before removal of the shell the prominent ventral foot, ill-defined head, and continuous mantle-skirt can be made out in ventral (fig. 3) and side view of the body.

(*a*) The oval muscular Foot has a well-defined wavy edge which separates a smooth ventral surface from the smooth sides. Laterally and posteriorly the latter rise almost vertically to the insertion of the mantle, and anteriorly become continuous with the head.

(*b*) The Head, as seen from the side, is a prominent muscular projection overhanging the front end of the foot (fig. 5). In shape it may be compared to a truncated demi-cone with the cut end turned forwards, rounded off, and bent somewhat downwards to form a snout, the circular muscle in the wall of which is very well developed, and is practically a sphincter. The flat side of the demi-cone faces downwards, and is marked off by a distinct transverse groove from the snout. On either side of the groove is a well-marked retractor muscle band connecting the head with the side of the foot. The upwardly facing curved surface of the demi-cone is continued backwards till it passes into and becomes the floor of a cavity of which the wide opening can be seen above the head. This is the Nuchal cavity.

The transversely oval mouth situated at the front end of the head is bounded by a continuous frilled lip, having a reniform outline resulting from an indentation of its ventral half. The lip is clearly divided into a long dorso-lateral portion and a short sharply incurved ventral portion. There is a depression at the junction of these two parts on either side. The mouth area faces downwards, and is placed on the end of the freely-projecting truncated end of the demi-cone, to which the term "snout" has been applied. The form of the mouth and lips is evidently adapted to the process of scraping forwards by which the animal feeds, and there is a marked contrast with the vertically elongated seizing mouth of a *Haliotis* or a *Pleurotomaria*. The snout is devoid of any power of introversion, and has no claim to be styled a "proboscis."

An elongated cephalic tentacle, swollen at its base, is attached on either side just behind the snout in line with the front end of the retractor muscle band, which runs back from the head to the foot. The eye is visible as a small black pigment spot on the posterior side of the thickened base of the tentacle.

(*c*) The MANTLE is a continuous flap or skirt, running completely round the body and lining the marginal part of the shell. The pallial impression is due to muscle fibres which take origin not far from the mantle edge and are inserted into the shell over a continuous band-like area a little above the margin. The mantle is of greatest extent in front, since here it roofs the nuchal cavity, the opening of which has already been seen. The edge of the mantle is pigmented and slightly thickened, and it bears numerous pallial tentacles each arising from the bottom of a pit into which it can be retracted. In a living animal, observed when covered with sea water, these organs can usually be seen projecting as a delicate fringe beyond the edge of the shell. The pallial tentacles are of two kinds, large and small, arranged in a regular manner, the latter being by far the more numerous. There may be over three hundred tentacles in a large specimen, and the number appears to increase with age. The mantle bounds externally a deep groove, the pallial cavity, the inner side of which, except in front, is formed by the side of the foot. Above the head a large transverse opening leads into the nuchal cavity already mentioned. This may be regarded as a local deepening of the pallial cavity, originally formed as a "branchial cavity" to shelter Ctenidia.

Projecting from the inner surface of the mantle are a large number of plate-like pallial gills, which are flattened in a direction perpendicular to the curve of the mantle outline. They form a continuous series right round the body, except at the left end of the nuchal opening (fig. 3); at this point the pallial vein, which completely encircles the gills, runs in to enter the heart. These pallial gills are secondary structures, which have replaced the primary gills, or ctenidia, just mentioned.

After removal of the shell the following points can be made out in dorsal view (fig. 4):—

(*a*) The shell muscle shaped like a horse-shoe with forwardly directed thickened ends. It is divided into a variable number (12-17) of fasciculi, separated by transverse fibrous septa.

(*b*) The mantle skirt running right round the body external to the shell muscle. In front it extends backwards for a short distance between the ends of this muscle to constitute the roof of the nuchal cavity. Just external to the shell muscle is seen the band of attachment of the pallial muscle to the shell. Just internal to the anterior part of this attachment band there is a very well marked second line of attachment running between the tips of the shell muscle and indicating the front boundary of the nuchal cavity. This is the internal pallial muscle. The mantle is pigmented dorsally near its edge, and so also is its band of muscular attachment, but the attachment zone of the internal pallial muscle is not pigmented.

(*c*) The low visceral hump occupies nearly the whole space within the shell muscle, and is therefore oval in outline, but the front end is truncated where it adjoins the back of the nuchal cavity. The hump is covered with a very thin layer of black pigmented epithelium which can be brushed off without difficulty; limpets are largely exposed to the baking action of the sun and this pigment may have been developed as a protective measure. After its removal the following organs are seen by transparency (fig. 4):—

(*d*) The dorsal surface of the digestive gland occupying the central region.

(*e*) A superficial loop of intestine dividing off an obliquely oval patch in the centre. The two limbs of this loop run out to the edge of the mass near its right anterior corner.

(*f*) More or less of the coiled stomach, external to the left limb of the loop (*e*) above and concentric with it.

(*g*) The rectum running transversely a little way in front of the stomach, and bending forward on the right to reach the nuchal cavity.

(*h*) The somewhat triangular pericardium occupying the left front of the visceral mass. One side of it abuts against the left end of the shell muscle, a second side runs obliquely inwards from the shell muscle on the left to the nuchal cavity on the right, while the third side abuts upon the nuchal cavity. The second side is approximately parallel to the rectum which is a little way from it. The left front corner of the triangle is continued along the rounded left end of the shell muscle as far as the attachment of the internal pallial muscle.

(*i*) The kidneys, two in number, (1) a small left kidney between the rectum and the right side of the pericardium; (2) a very large right kidney, of which two diverging lobes almost completely encircle the visceral hump except at the extreme left front. The visible parts of the kidneys lie very superficially, closely bound to the visceral integument, and their boundaries can, as a rule, only be clearly seen in injected specimens, since, in uninjected ones, the digestive gland often shows through by transparency. As the renal waste is dark coloured, the kidney is fairly often naturally tinted so as to make its outline clear.

III. NUCHAL CAVITY AND RELATED APERTURES.—The continuous mantle cavity which lodges the pallial gills deepens in front to form a fair sized nuchal cavity, so-called because it lies above what may be called the neck region of the animal. It opens by a wide slit between the anterior ends of the shell muscle. Its roof is formed by a backward extension of the mantle, and its floor by the muscular body wall of the neck region. With the exception of the mouth, all the apertures of the body open into it, *i.e.*, the anus, the left renal opening, and the right renal opening (figs. 4 and 5). When the cavity is opened by careful removal of its roof the following structures can be made out:—

(*a*) The anal papilla opening into the back of the cavity upon the animal's right shoulder.

(*b*) On either side of this a renal papilla, the right being rather more conspicuous than the left.

(*c*) The pericardium, which bulges into the cavity along a line from the left tip of the shell muscle nearly to the left renal papilla.

(*d*) The pallial vein (also visible from outside before opening the nuchal cavity) at the left side of the cavity, running into the pericardium.

(*e*) The small "pulmonary veins" running in from the roof of the nuchal cavity (visible before opening) and piercing the pericardial wall to the right of *d*.

(*f*) The pair of sensory patches or osphradia, which probably cover the vestiges of the ancestral pair of ctenidia. Each structure is a minute orange or reddish coloured elevation on the floor of the nuchal cavity close against the shell muscle on either side. It is nearer the back of the nuchal cavity than the tip of the shell muscle. These structures prove that the nuchal cavity is really a branchial cavity of which the ctenidia have degenerated.

Body Wall, Muscular System, and Mantle.

The body of Patella is covered by a layer of columnar epithelium which in most parts possesses a well-developed cuticle. That covering the visceral hump is mostly black-pigmented as already mentioned; that covering the regions of muscular attachment is, as might be expected, much flattened. A great deal of the epithelium is ciliated in young animals. Unicellular glands are not common in the epidermis, but a few occur in the foot and mantle; they are of the usual goblet type. The covering tissues will be discussed in greater detail in connection with the various organs.

Muscular System.—Though muscle fibres are found in almost every part of the animal, there are special aggregations of them which need separate mention. These are the body-wall muscles of the head and neck, the foot, the shell muscle, the pallial muscles, and the muscles of the odontophore. The last of these will be described in treating of the odontophore.

The muscles of the dorsal body-wall in the head region comprise the following layers:—

(*a*) An outer transverse layer, (*b*) a layer of longitudinal and obliquely arranged fibres which are head retractors. There are also some fibres running transversely internal to (*b*).

The ventral body-wall in the head region is thicker, but possesses almost solely transverse and oblique fibres. The muscle of this region is continuous with that of the foot and shell muscle.

The general appearance of the foot has already been described. It is essentially a thickening of the ventral body wall made up, for the most part, of bundles of muscle fibres bound together by connective tissue. In the ventral part the fibres run in all directions, while in the dorsal part they are mostly horizontal and oblique. The fibres in the outer portion of the foot are steeply oblique, and these, together with some of the dorsal fibres, are continuous with the shell muscle. The absence of a horizontal circular muscle, and the many differences between the disposition of fibres here and in the suckers of various animals, tell against the hypothesis of a sucker-like action of the foot, which, as was said above, is also not supported by observation. The spaces between the bundles of muscle fibres contain blood and, when full, make the foot swell far beyond its usual size. Two of the blood spaces above mentioned are of special importance, they run along in the vicinity of the pedal nerve-cords, and it is from them that blood spreads to the remainder of the organ (fig. 8*a*).

In very young specimens (about $\frac{1}{4}$ in. long) there is a distinct glandular outgrowth from either side of the foot, which disappears more or less completely when the animal gets older. The outgrowth is, from its position and histological characters, the homologue of the "lateral streak" in *Nacella*, etc. There is also a rudimentary flap covering the glandular tissue in the anterior region, where also the whole structure is best developed. The persistence of this glandular tissue is possibly connected with the protection of the young animal against desiccation, to which it is specially liable in its habitat far up the tidal zone, and because of the greater ratio of surface to volume in smaller than in larger forms.

The foot (fig. 8*a*) is covered externally by a layer of columnar epithelium, which possesses more or less of a cuticle, with goblet cells here and there. The cells on the side of the foot are small, but increase in height towards the ventral surface, where they are fairly long and regular, with nuclei usually near the base. The ventral covering, as might be expected from the amount of wear to which it is subjected, seems to be shed frequently. The epithelium of the sides of the foot is thrown into a number of small ridges, which, in very young specimens, are found nearly up to the mantle attachment, but in older animals are mainly restricted to the part near the ventral edge. Internal to the epithelium of the sides of the foot is a deeply staining layer with nuclei, which is apparently a sub-epithelial nerve plexus, and from it there proceed outwards narrow deeply staining cells which are probably sensory. Beneath this covering tissue is a dermis, an irregular network of connective tissue with blood spaces which are more numerous internally. The dermis is thin at the sides of the foot. Along the anterior border of the foot there occur several small glands opening near the edge of this organ.

Internal to the dermis are found the muscle bundles which make up the main mass of the foot. Most of these bundles are continuous with those of the shell muscle, and, in fact, the horse-shoe impression might be spoken of as the area of attachment of the muscle fibres of the foot. Of these bundles the outer ones proceed downwards in a steeply oblique direction, while the inner ones curve in and become the slightly oblique bundles which form the dorsal part of the foot. Between these bundles are numerous blood spaces, the most important pair of which have already been mentioned. It is the quantity of blood in these spaces that governs the turgidity of the foot and therefore its functional activity. Besides the above muscle fibres there are others which run horizontally and obliquely especially in the ventral part. The muscle bundles are wrapped in connective tissue.

The lateral glandular streak is a much larger projection than the puckerings of the side surface of the foot and it occurs amongst these just below the ventral limit of the mantle cavity, extending backwards a variable distance on each side. It consists mainly of tubular gland tissue, the upper surface of which is covered by small columnar epithelium as also is the under surface except where the glands open. There is very little connective tissue between the glandular tubes. The epidermal and sub-epidermal tissue just ventral to the projection is to some extent vacuolated. A variable number of muscle fibres go out to the projection, and dorsal to it, in the anterior region, is found a vestige of a flap formed by muscle fibres and connective tissue covered by epithelium.

The muscles are composed of smooth fibres. These may be scattered, when they are seen to be each an elongated cell with lateral nucleus, or aggregated into bundles, as in the shell muscle. None of the fibres of this muscular tissue show striation.

The Shell Muscle.—The bundles of oblique fibres forming the dorsal part of the foot are continued around its dorsal rim into the shell muscle, so called because its fibres are attached to the shell (by means of a compressed epidermis). This muscle encircles the visceral hump except at the anterior end where it is wanting across the neck region, it is therefore of a horse-shoe shape and the anteriorly placed ends of the horse-shoe are enlarged.

The fibres of this muscle are closely packed and aggregated into 12-17 bundles, each surrounded by connective tissue. Through this connective tissue run the afferent blood spaces of the mantle, gills and mantle skirt. Embryological evidence, derived from *Acmæa*, shows us that this type of muscle has arisen by enlargement backwards of a pair of lateral muscles. Such a paired condition exists only in *Haliotis* and *Scissurella* among recent Gastropods, and in the former the left member of the pair is almost vestigial. The columellar muscle of the typical Prosobranch is the modified right member of the ancestral pair. The outer more steeply oblique fibres of the shell-muscle in *Patella* pull down the edge of the shell by their contraction, while the medianly running inner ones exert downward and inward traction which must greatly strengthen resistance to lateral blows. The latter fibres are more numerous in Patella than in more primitive Docoglossa (*e.g.*, *Acmæa virginea*).

The Pallial Muscles attach the mantle skirt to the shell all round and will be described in the account of the mantle which follows. Their insertion into the shell has already been mentioned.

The Mantle Skirt is covered dorsally by a layer of columnar epithelium which passes gradually into the flat pigmented epithelium covering the visceral hump. Peripherally it is thrown into a large number of folds (fig. 8) parallel to the free edge, the cells on the crests of these folds being very much elongated. Near the extreme edge of the mantle on the dorsal side the epithelium is not folded in this way. There is a broad pigmented band outside and concentric with the shell muscle and a narrower and less continuous band of the same character a few cells from the free edge of the mantle, the mantle edge itself is also pigmented (fig. 8*a*). The epithelium covering the attachment of the pallial muscle is compressed and pigmented, and that covering the internal pallial muscle between the tips of the shell muscle is compressed but not pigmented. The epithelium clothing the under side of the mantle skirt is also columnar, folded to a less extent, and not pigmented. The ventral epithelium of the nuchal roof is shortly columnar. Many of the epithelial cells of both the dorsal and the ventral epithelium, are clear and glandular, and near the edge of the mantle skirt a great deal of sub-epithelial glandular tissue is present, one set of glands opening at the extreme edge of the mantle and the others further ventrally. These glands secrete the material for the outer shell layers. Many sense cells are present in the epithelium of the mantle and of its tentacles, which are best described in a separate paragraph. These are particularly abundant in the epithelium of the dorsal side just near the free edge which, as has been stated, is not folded.

The substance of the mantle, including the roof of the nuchal cavity, is made up of a basis of connective tissue containing numerous blood spaces and traversed by muscles and nerves. The blood spaces in the roof of the nuchal cavity are specially large and are traversed by distinct trabeculæ of connective tissue. This fact, combined with the comparative thinness of the epithelium, is in itself adequate evidence of the respiratory function of the nuchal roof. The other more regular blood spaces are best considered along with the remainder of the circulatory system and with the pallial gills.

The chief aggregates of muscle fibres are those forming the pallial muscle and the transverse band which we have called the internal pallial muscle.

The fibres of the pallial muscle take origin in the pallial impression of the shell and then travel outwards, radiating into the mantle edge which they serve to retract and into the sub-epithelial tissue of which they are inserted. They also furnish the retractor muscle slips which run into the pallial tentacles. The fibres of the internal pallial muscle take origin in the corresponding transverse impression, and form a definite layer of radiating fibres, which are also inserted into the mantle skirt nearer the edge than the level of origin of the other pallial muscles. A continuous ring-nerve runs round in the tissues of the mantle skirt. It is formed in front by the anastomosis of the anterior branches of the pallial nerves, and behind by the fusion of the posterior branches of the same nerves (fig. 24). From the outer side of this ring-nerve numerous twigs are given off, which break up into a network from which branches pass into the pallial tentacles.

Digestive Organs (figs. 4, 6, 10, 11-22).

These consist of a very long and complex Gut and some important Glands which open into it. The mouth opens into a buccal mass (containing the Odontophore), which is succeeded by gullet, crop, stomach and long intestine, the last part of which is the rectum. There are buccal ("salivary") glands opening into the buccal mass and a large digestive gland or hepato-pancreas ("liver") opening into the stomach.

I. The Gut.—This complicated tube is formed of many coils arranged in a characteristic manner. We now proceed to the detailed description of its various parts.

The *Buccal Mass* (fig. 6). This is best exposed by lateral incisions of the anterior part of the body wall. Connect these by a transverse incision near the tentacle bases and carefully peel off the dorsal body wall from before backwards, noting that the gullet is very liable to be damaged in the process on account of its intimate connection, by means of fibres, with the body wall.

The buccal mass, as seen in dorsal view (fig. 12), is roughly rectangular in outline with the broad sides lateral. The anterior quarter of the rectangle contains the buccal cavity and the remainder constitutes the broadened anterior end of the radular sac, the rest of which will be seen later. The gullet is a thin-walled tube which opens at the junction of these two regions, and then runs backwards covering and concealing from view the radular sac. The four buccal ducts (fig. 16) are seen running forwards with a somewhat wavy course, the two outer lie freely at the sides of the gullet, the inner run above the dorsal wall of the gullet to which they are closely attached. All four ducts open at about the level of the beginning of the gullet by piercing two thickened dorso-lateral areas, which will be discussed later on in connection with the glands. The gut cavity is wider at this level than further back, and these thickenings have been homologised with the dorso-lateral buccal pouches of *Haliotis*.

The *Buccal Cavity* is best studied by comparing the results of median dorsal incision, lateral incision, longitudinal median section, and transverse section in a few specimens (figs. 6 and 12). The following points are to be noted:—

(*a*) The situation of the cavity.—As the mouth is ventral, the morphologically front and back ends of the cavity are topographically ventral and dorsal, while the morphological roof and floor are respectively anterior and posterior. In describing the cavity we shall refer to the parts in their morphological relations. The main or palatal buccal cavity has a posterior extension, which we shall call the post-palatal buccal cavity, situated on the dorsal side of the odontophore under the commencement of the gullet (fig. 12). This cavity narrows behind into the radular sac.

(*b*) Within the dorsal and ventral outer lips an inner lip is present on either side as an upwardly growing fold (fig. 6). Boutan refers to this pair of lips as "*une lèvre en forme de fer à cheval.*" These two lips can be approximated so as to close the mouth almost entirely. A median papilla, or "licker," belonging to the odontophore, projects between the lips so as to completely fill the chink between them when the mouth is closed.

(*c*) The dorsal palatal plate is a chitinous sub-epithelial thickening forming an arch over the region of the inner lips. It imparts firmness to the lip and also serves to lift the tissues connected with it out of reach of the rasping radula. It is prolonged into two pairs of expansions, one pair dorso-lateral and one pair ventro-lateral (fig. 11). This plate is most probably a pair of jaws united by a median dorsal piece.

(*d*) The front end of the odontophore or rasping organ projects into the palatal section of the buccal cavity from its postero-ventral wall, and the front end of the radula, a horny tooth-studded ribbon, occupies a narrow median strip on this projection (fig. 12), extending backwards on the posterior part of the odontophore cushion, which is placed beneath the floor of the post-palatal section of the buccal cavity (*a* above) underlying the gullet. The epithelium covering the tip of the odontophore, anterior to the radula, has grown out into a transversely ribbed projection, which is the papilla, or "licker."

(*e*) The sub-lingual pouch is a recess below the front end of the odontophore (fig. 6). It is found in *Chiton* and many other forms. In *Patella* it is lined by yellowish epithelium and contains mucus-secreting cells in its roof.

(*f*) The floor of the buccal cavity is muscular with a slight sub-epithelial median development of chitin.

(*g*) The odontophore and its muscles are described later on.

The *Gullet* (figs. 6, 10, 15, 16, 22) runs back as a thin-walled tube from its point of junction with the buccal mass, overlying the central part of the posterior two-thirds of this. Immediately behind the buccal mass it shifts slightly to the left of the median line and merges into the thick-walled crop, dilating into two ventro-lateral œsophageal pouches just before the point of junction (fig. 10). The œsophageal pouches are in part spare tissue for the purpose of avoiding strain when the buccal mass is extruded for feeding. They are probably homologous with the lateral œsophageal pouches of *Pleurotomaria* and *Haliotis*, though their functions cannot be quite the same, as in these two forms they are lined by ridged glandular epithelium, while in *Patella* they are comparatively smooth, and not markedly glandular. The gullet has various folds (figs. 15 and 22) as follows:—

(*a*) A transverse section taken near the posterior end of the buccal mass, shows the gullet as a dorso-ventrally flattened structure, the central portion of which is marked off from the sides by two long folds projecting downwards from the dorsal wall.

(*b*) There are a pair of longitudinal ventral folds starting slightly behind the junction of the gullet and the post-palatal section of the buccal cavity. These folds converge as they run back, and the triangular space between their front ends is marked by slight transverse ribs. It seems to correspond with the much better developed "ventral valve" of this region in most primitive Prosobranchs.

(*c*) A number of small oblique folds lie external to each ventral fold.

The great width of a posterior section through the gullet is due to its ventro-lateral extension into the œsophageal pouches. These occupy part of the space at the back of the buccal mass and are not sharply marked off, being, as it were, mere bulgings of the gullet. The lumen of each pouch is continued forwards into that part of the gullet cavity lateral to the dorsal fold of its side. The gullet is, to some extent, asymmetrical on account of the shift to the left where it merges into the crop.

The *Crop* (figs. 10 and 18).—On passing into the visceral mass the food tube shifts further to the left of the median line and its walls become very much thickened. This thick-walled region is called the crop. It is imbedded in the visceral mass and care is needed to expose without damaging it. The buccal and digestive glands adhere to its walls, and various gut coils also hide it from view. In this imbedded position it runs back some distance, becomes much narrower, and then passes to the right and runs forward.

The lining of the crop projects internally to form the following folds:—

(*a*) The continuations of the longitudinal dorsal folds of the gullet. These folds pass down the left side of the gut-wall and become mid-ventral, thus indicating that the crop has been subjected to a torsion of 180° relative to the head. Further back, these folds run up the right side showing an additional torsion of 90° or more (fig. 22).

(*b*) The continuations of the ventral longitudinal folds of the gullet. These have fused basally, so we find a single outgrowth branching distally into two. This keeps at a uniform space of 180° from the dorsal folds and so is twisted round through the same angular distance (fig. 22).

(*c*) Obliquely transverse folds running across the wall space from the single divided fold (*b*) almost to the pair of folds (*a*) (fig. 18).

Where the crop narrows down posteriorly the transverse folds of its walls cease, but the longitudinal ones are continued until the gut begins to run forward on the right side. At a certain level all folding ceases, and this point should probably be taken as the termination of the crop.

The *Stomach* (figs. 4, 6, 10, 19, 20).—Beyond the crop, the now thin-walled gut runs forward for a short distance and then bends over on itself and becomes a large coil which encircles the dorsal surface of the digestive gland. The whole of this region may be called stomach. At the point where the stomach bends over on itself the duct of the digestive gland opens into it on the left (fig. 19). This opening is fairly conspicuous, and the wall of the duct has a groove with thickened projecting sides (figs. 19 and 20). This groove is continued along the inner wall of the stomach throughout the whole of the superficial coil, and becomes indistinct where the stomach narrows down and passes into the intestine at the right side of the visceral mass. At the point of bending, near the opening of the duct, there is an inward flap-like projection of the posterior wall (fig. 19).

Intestine.—Numerous coils of intestine (figs. 4, 6, 10, 21) form the remainder of the gut.

(*a*) A coil following the stomach, running back along the right side, then round just ventral to the crop, returning finally to the right anterior corner of the visceral mass. This coil has a relatively wide cavity (fig. 10, *Int.* 1).

(*b*) A coil on the dorsal surface of the visceral mass within the stomach coil (fig. 10, *Int.* 2). The anterior limb of this coil communicates with the end of *a*, and the posterior limb with the posterior limb of *c*.

(*c*) A small coil ventral to (*a*) (fig. 10, *Int.* 3). Its anterior limb passes, at the right anterior corner of the visceral mass, into

(*d*) a long coil (fig. 10, *Int.* 4) which first passes over the right anterior corner of the visceral mass and then proceeds beneath the pericardium and around the external border of the stomach to about the middle of the right side, when it turns back and forms

(*e*) the last coil (fig. 10, *Int.* 5), which is in close contact with (*d*) until it reaches the pericardium, when it proceeds along the posterior edge of this to the animal's right shoulder and opens on the anal papilla. The last part of this coil (*e*) is the rectum. Its ventro-lateral wall has two inwardly projecting ridges with a gutter between them. The anus opens at the tip of the anal papilla which projects into the nuchal cavity on the right shoulder (fig. 4). The walls of this projection are much thickened, and its lining is papillated. The ventro-lateral ridges of the rectal wall become more strongly marked as the walls thicken towards the anus (fig. 21). Judging from the condition in other Gastropods it would seem probable that the rectum once ran forward in or near the median plane traversing the pericardium. The shifting of the anus to the right side, and of the pericardium to the left, has made the rectum lie across the body, and has pulled out the whole of the last coil of the gut so that it now lies on the extreme outside of the hump around the left side of the latter.

II. The Large Glands of the Gut.—The *Buccal Glands* (figs. 6, 15, 16) are four compound orange-coloured tubular glands occupying the front of the visceral hump below the pericardium and rectum. They are usually united practically into one mass, but occasional specimens show, anteriorly, more or less division into four (fig. 16). The two inner ducts run in the grooves formed externally by those inward projections into the gullet cavity, called above the dorsal longitudinal folds. Free at first, they become, towards the front end, involved in the gullet wall (fig. 15), but they run along in it and only open at about the same level as the outer pair. The two outer ducts run freely at the sides of the gullet, and open into slight lateral pouches in the buccal cavity behind the palate; they often have ampullæ placed at irregular intervals along them (fig. 16). Cuvier noticed small patches of yellowish tissue near the openings of the buccal ducts, and named them "salivary glands." It is interesting to note that similar yellowish glandular masses occur in the pharyngeal wall of *Fissurella* near the opening of its (one pair of) buccal ducts; these Boutan has unhesitatingly called traces of another pair of buccal glands.

The *Digestive gland*, or Hepato-pancreas ("liver"), is a large racemose gland, occupying the centre of the visceral mass (figs. 4 and 6). The bilobed condition, which is primitive for Mollusca, may have disappeared long before the differentiation of the Docoglossa, or may be obscured by the consolidation and compression which the viscera have undergone in this group. The ducts of this gland converge into two main ducts, which unite just before they open into the stomach, as described above. The ridge-bounded groove on the internal wall of the stomach is continued on the floor of the main duct and even of its first branches.

Histology of the Gut and Glands.

The digestive tube is lined throughout by columnar epithelium, many of the cells being ciliated, others glandular, and a cuticle being developed in some parts. Beneath the epithelium the wall consists of connective tissue and elongated muscle fibres. The size of the lumen of the gut varies considerably in different parts, as also does the thickness of the walls. The cavity of the gullet is extensive (fig. 15), while its walls are very delicate and closely bound dorsally, by strands of connective tissue, to the outer body wall covering the head. The crop has thick walls and a correspondingly reduced cavity (fig. 22), while the stomach has a very wide cavity with rather thin walls; the succeeding coil of the gut is narrower and thin-walled, and the remaining coils are still narrower; the rectum is thicker walled (fig. 21).

The sub-lingual pouch, like the rest of the gut, is lined by columnar epithelium, which here has a distinct yellow colour, is largely glandular, and probably mucus-secreting. The region of the buccal cavity, into which the buccal glands open, has its walls yellow tinged and somewhat thickened, the thickening being due to the presence of the small tubular glands previously mentioned. Their cells resemble those of the buccal glands. The crop has a greater development of sub-epithelial tissue than is possessed by other parts of the gut, but the major part of the thickening is due to the epithelial folds projecting into its cavity.

The longitudinal folds are covered by high columnar epithelium, which includes a large number of glandular cells. Many of the cells contain rounded granular highly refractive bodies. Under the epithelium of each fold is a distinct, mainly fibrous, band which can be traced outwards through the thickness of the crop wall. The transverse folds are infoldings of the side walls between the longitudinal folds just mentioned. They connect with the single divided longitudinal fold, but not with the pair of longitudinal folds. Each of these folds has secondary foldings on itself, and these run approximately along lines radiating from the centre of the crop. Near the inner and free edge of the fold are smaller papilla-like outgrowths (fig. 18).

The stomach is lined by columnar epithelium, with subjacent connective tissue which is not very abundant. The epithelium is fairly even all round except along a line on the internal wall where we find a groove formed by the upgrowth of two ridges. The height of these ridges is due mainly to the unusual height of the epithelium along them, while the cells lining the groove are very short (fig. 20). This description is correct for a young limpet, but as the animal grows older the groove deepens.

Much of the intestine has ridged walls. The rectum shows two ventro-lateral folds, which are covered by fairly high columnar epithelium, growing into its cavity and forming a gutter between them. These folds become much more distinct on the anal papilla (fig. 21), and here they branch into secondary foldings. Fæces seem to be extruded only from the upper section of the rectum, dorsal to the "gutter" and folds.

The buccal glands are made up of much branched tubes which are imbedded in connective tissue, and the glands, for this reason, have the appearance of one large mass. The cells lining the gland tubules are large and contain numerous granules, they are fairly equal in size and have large and distinct basal nuclei. The cells near the apices of the tubules appear not to be ciliated, but those further towards the ducts possess cilia and have smaller nuclei.

The digestive gland is similarly a great mass of branching tubules imbedded in connective tissue. The cells lining these tubules vary a good deal in size and shape but are very distinctly glandular, and usually so gorged with droplets of a yellowish-green secretion and fine granules that they burst while being prepared for microscopic examination (fig. 17). The ducts of the digestive gland are lined by ciliated columnar epithelium resembling that of the general gut lining. Miss Newbigin finds that, in sections of specimens hardened in formalin, the epithelium lining the intestine has a band of brownish green pigment near the inner margin of the cells. When examined under a higher power the pigment is seen to occur in minute closely packed granules, brownish green in mass, green when viewed singly. The cells of the digestive gland vary in size, the large cells near their inner surface contain several of the characteristically molluscan pigmented vesicles, usually of a brownish yellow colour, while scattered through the protoplasm occur numerous oil drops. The presence of varying amounts of a pigment, called enterochlorophyll, causes great variations in the colour of the digestive gland. The same pigment also occurs in the fæces.

III. The Odontophore (figs. 6, 12, 13, 14).—The Odontophore, or rasping organ, characteristic of all cephalous Molluscs, arises in development as a ventral pouch of the fore gut, the ectoderm of which, together with the underlying mesoderm, ultimately gives rise to :—

(*a*) A projection on the floor of the buccal cavity—the Cushion (Mesodermic).

(*b*) A pouch—the Radular Sac, formed of ectodermic epithelium, with a little subjacent connective tissue.

(*c*) A horny tooth-studded ribbon, the Radula, of which the part in use rests on the surface of the cushion, while the parts in reserve and in course of formation are lodged in the radular sac.

The *Cushion* is the projection on which the radula rests, and whose movements enable that organ to perform its scraping function. It consists essentially of muscles and four pairs of cartilages, and is covered above by the fore gut epithelium and that of its diverticulum, the radular sac. The radula is placed in a median groove on the dorsal surface between the paired cartilages (fig. 12).

The cartilages are best named Anterior, Antero-lateral, Ventro-lateral and Posterior. Their shapes and relations are most suitably explained by diagrams (fig. 13). Each anterior cartilage has a ridge towards its front end, acting as a lateral pad for the radula. The cartilage is of the type called spongy, as it consists of fairly large, clear, nucleated cells, separated by a comparatively small amount of structureless intercellular substance. The antero-lateral are placed at the sides of the anterior cartilages near their front ends, and give the cushion its characteristic broad front. The ventro-lateral cartilages, first noticed by Amaudrut, are very small, and on the ventral surface of the cushion. The posterior cartilages are well developed, and not so ventral as in some Rhipidoglossa.

The muscles of the Odontophore include (1) Extrinsic Muscles, connecting the odontophore with the walls of the buccal chamber, (2) Intrinsic Muscles, connecting the cartilages with one another and with the sub-radular membrane.

The chief Extrinsic Muscles are:—

(*a*) The large ventral protractor muscles attached posteriorly to the ventral part of the posterior cartilag and spreading out towards their anterior origin behind and at the base of the inner lips.

(*b*) Dorso-lateral protractor muscles attached at the front end around the expansions of the dorsal palatal plate, and, behind, to the sides of the posterior cartilage.

(*c*) Antero-lateral retractor muscles going from the sides of the anterior cartilages to the floor of the neck cavity. These may be divaricators of the cartilages.

(*d*) Numerous fibres, more or less irregularly arranged, and including some posterior ventral retractors going from the odontophore to the floor of the neck cavity. The protractor muscles seem to be by far the most important, and probably, therefore, the act of retraction is mainly a natural relapse to normal conditions from a state of strain.

The chief Intrinsic Muscles (fig. 13*b*) are:—

(*a*) Two transverse layer-like bands connecting the ventral sides of the anterior and lateral cartilages together. These are separated by (*b*).

(*b*) A pair of muscle bands .going forwards from the posterior cartilages to the epithelium beneath the front end of the radula.

(*c*) Muscle bands connecting the anterior and antero-lateral cartilages dorsally, and

(*d*) Muscle bands connecting these cartilages ventrally.

Besides the above muscles, various bands of connective tissue bind the antero-lateral and the posterior cartilages to the anterior, and some further minute details are shown in the figures (figs. 13*a*, *b*, *c*).

The *Radular Sac* (figs. 6, 12) is a long cylindroidal diverticulum of the post-palatal section of the buccal cavity. Arising at the upper limit of the back of the cushion, it first runs downwards close to this, and then, ter a swerve to the left, bends back along about two-thirds of the under surface of the visceral mass in the median plane. It then curves well round to the right side, taking a forward course to about the middle of the visceral mass, after which it bends sharply upon itself and retraverses the greater part of its former course. This second part is closely applied to the right side of the first, and its caecal tip extends forwards almost as far as the back of the cushion. The anterior part, at least, of the radular sac and the odontophore, are surrounded by a large blood space, whence blood travels both to the visceral hump and to the foot.

The *Radula* is altogether about twice the length of the animal, and is a narrow belt-like structure with rows of teeth, having at its anterior end a flat plate-like expansion on either side. This plate is bent over the front end of the cushion where the covering epithelium has secreted it. Behind this the radula sinks into a groove along the middle of the odontophore and runs back into its sheath.

The teeth of the radula are arranged in convexly curved transverse rows, the convexity being forwards on the dorsal surface of the cushion. There are twelve members to each row (fig. 14). Of these twelve the four central ones are similar, although the middle two are slightly smaller than the others. Each consists of a yellow stalk and a black-tipped brown "claw," the claw having its concavity directed backwards. Next to these four and behind their level is another tooth of the same kind but larger and with three claws. Lateral to these again we have three pairs of teeth without claws, these have their ends curved slightly backwards. They are at the same level as the four central teeth.

The absence of one definitely differentiated median tooth characterises all the Docoglossa except the Lepetidæ, and other special features are the fewness of teeth in each row, and the high degree of specialisation of the individual tooth. These characters sharply differentiate the Docoglossa from other Gastropods, for the specialisation of their radula is certainly along a line diverging absolutely from that adopted by the Tænioglossa, where the fewness of teeth per row is due to several having fused to form compound ones.

To this account of the alimentary canal we may add a short description of the relations of the various parts of the fore-gut to the feeding process. The generalised diagram of a median longitudinal section of *Patella*, given in fig. 6, is intended to illustrate these relations.

By contraction of its strong ventral protractor muscles the tip of the odontophore is extruded from between the lips, and the radula is rubbed along the rock surface from behind forwards to scrape off minute Algæ. The outer lips, aided by the "licker," seize and hold any fragments torn from the rock, the dorsal palatal plate greatly strengthening the dorsal outer lip for this purpose, besides lifting the roof of the buccal cavity out of reach of the rasping radula. The food, consisting of small Algæ and tiny organisms of various kinds, with an admixture of rock substance, is then passed into the buccal cavity from which its exit is barred by the closure of the inner lips. The mouth parts are almost always examined when both they and the head are in a retracted condition, and it may be that the œsophageal pouches are, in part, spare folds of tissue allowing the protrusion of the odontophore without breakage of any of the gut lining. Specimens paralysed by a dilute solution of chloral hydrate in sea water often die with the head partly expanded, and they certainly seem to show less folding in the region of the œsophageal pouches.

Patella also feeds in another way by gripping a piece of seaweed with its outer lips (aided by the palate) and then scraping off fragments from it by the rasping action of the radula. The mechanism for retracting the odontophore is not as manifest as that for its extrusion, and this process is probably in part a return to normal conditions from a strained state of expansion. The slightly developed retractor fibres, the cessation of contraction of the protractors, and the antero-lateral muscles probably all help, and assistance must also be given by the contraction of the muscular snout.

While the tip of the radula is scraping food from the rock, another part of it is, by the same motion, working against the jaw, or palatal plate, and thus helping to grind the food already obtained. This working of the radula against the jaws continues after actual feeding has ceased, and the œsophageal pouches seem to retain the food fragments temporarily till this function has been completed, and till they can be passed on into the crop. This passing on is necessarily slow on account of the many folds projecting into the cavity of the crop. Meanwhile, also, the food becomes mixed with the secretion of the buccal glands.

It is noteworthy that the œsophageal pouches of Patella do not show the development of folds and papillæ which characterises presumably homologous structures in the primitive Rhipidoglossa, and another feature is that the dorsal and ventral valves, which in the latter, and even in *Acmæa* (dorsal valve), prevent passage of the food from the pouches back into the buccal cavity, are very much reduced or absent. The pouches are therefore probably, in part, spare tissue and, in part, temporary stores, and not highly specialised secretory regions, as in *Haliotis*, and other Rhipidoglossa. The corresponding secretory function is performed by the crop, which is extremely specialised among the Cyclobranch Docoglossa, and thereby gives evidence of the difficulty of digesting the tough vegetable food; the high development of folds must also enable this region of the gut to act as a strainer, preventing the further transport of large fragments into the thin walled regions which follow. The great length and size of the stomach, which is the region where the secretion of the great digestive gland becomes mixed with the food is a further testimony to the slowness and difficulty of the digestive process.

Nervous System and Sense Organs.

The nervous system of *Patella vulgata* (fig. 23) may be considered under three headings.

(*a*) The Circumœsophageal ring with its cerebral, pleural and pedal ganglia, and the principal nerves thence given off except—

(*b*) The Buccal and Labial nervous systems, connected to the ring at the cerebral ganglia.

(*c*) The Visceral Loop and nerves thence given off, connected to the ring at the pleural ganglia.

The Circumœsophageal Ring.—This is seen, after exposure of the dorsal surface of the gullet, on pressing apart the gut tissues and body wall in the region of the head and neck. When completely exposed it is observed to be roughly four-sided, the plane of the quadrilateral sloping downwards and backwards, while its upper and lower sides are curved outwards. The quadrangular form of the ring is due to its having accommodated itself to the outlines of the buccal mass. Though certain swellings on the ring are referred to as ganglia, it must not be supposed that nerve cells are not found in other parts, the concentration of these being by no means complete. The two upper corners of the quadrilateral are set near the tentacle bases and are swollen to form the well-marked cerebral ganglia. These are connected by the cerebral commissure (forming the upper side of the quadrilateral) which runs across very far forward just beneath the dorsal outer lip.

The right and left sides of the quadrilateral (continuous above with the respective cerebral ganglia) have become double by separation of the connectives going to the pleural from those going to the pedal ganglia.

The lower side of the quadrilateral is a very short pedal commissure thickening at either end into the commencement of the great pedal nerve cord, which is ganglionic for a considerable portion of its length. The outer side of this anterior end of the pedal nerve cord is continuous with a short stout pleuro-pedal connective, and this latter thickens at the side and a little to the front into a pleural ganglion. From the ganglionic centres a number of nerves are given off, as follows (see fig. 23):—

(*a*) From each cerebral ganglion:

(1) The cerebral commissure, the cerebro-labial connective, and the cerebro-pedal and cerebro-pleural connectives.

(2) The branching tentacular nerve.

(3) The fine optic nerve supplying the eye which is placed on the posterior side of the base of the tentacle.

(4) Fine nerves (3 in number) going to the snout.

(5) A nerve which, for some distance, runs along with the cerebro-pedal connective, but which diverges from this at about the level of the pleural ganglia, going thence to the dorsal body wall.

(6) A nerve which is at first fused with the cerebro-pleural connective but soon becomes distinct from it and supplies the otocyst which lies at the base of the pleural ganglion against the pleuro-pedal connective.

(*b*) From each pedal cord, the anterior end of which may be called an ill-defined pedal ganglion:—

(1) From the anterior end, a nerve going forwards to the foot and ventral body wall.

(2) Nerves to the dorsal layers of the foot and to the shell muscle.

(3) Stout nerves to the ventral part (sole) of the foot.

(4) Fine nerves, those from one cord going towards those from the other. These nerves from the two cords unite in two cases forming anastomoses, of which one is close behind the pedal commissure, and the other quite posterior. It is probable that these nerves and anastomoses are vestiges of an ancestral ladder-like condition of the pedal cords and their interconnections.

(*c*) From each pleural ganglion:—

(1) Two small nerves (one more strictly from the cerebro-pleural connective and one from the ganglion itself) arising close together and supplying the dorsal body wall.

(2) A distinct nerve which seems to supply the anterior end of the shell muscle.

(3) A small nerve arising near the lateral extremity of the ganglion close to the origin of (4).

(4) The great pallial nerve, which soon divides into two:—(*a*) The anterior branch—this again divides usually into two; and (*b*) The stouter posterior branch—this runs outwards with the anterior branch and then turns backwards. At this point it may be seen just beneath the tissue covering the foot when the visceral hump is lifted off. This branch gives off, from its outer side, several nerves which run outwards to the mantle. Dr. J. Travis Jenkins has shown by minute dissection that an anastomosis does exist between the anterior and the posterior branches of the pallial nerve (fig. 24). It is,

however, hardly as direct as in the more primitive Docoglossa (*e.g.*, *Acmæa*). From the pleural centres are also given off the nerve bands which together form the visceral loop.

A first examination seemed to show a slender nerve connecting the two pleural centres together, and running just in front of the pedal commissure. Microscopic investigation, however, shows that this slender cord is a fibrous band connecting the two otocysts and extending beyond them to end in the dorsal surface of the foot.

The Labial and Buccal Nervous System.—A fairly thick connective arises from the inner border of each cerebral ganglion, and goes along the floor of the snout, very soon swelling into what may be called a labial ganglion. The commissure between the labial ganglia is thin and markedly curved, with the concavity forwards, the curve being underneath the sub-lingual pouch. The labial ganglia give rise to nerves going forwards to the lips, and, at the back, to a few supplying the snout muscles, &c. (see fig. 23). From each of these ganglia also arises a fine sinuous labio-buccal connective, which enters the tissue of the odontophoral cushion. When it reaches the dorsal surface of this organ it swells into an elongated buccal ganglion. The two buccal ganglia converge to some extent posteriorly, and are connected with one another by a well-marked commissure entering their posterior extremities. The buccal nervous system is easily seen on removal of the gullet and the radular sac, but the connection with the labial centres is difficult to trace. The labio-buccal connective gives off a nerve to the anterior parts of the odontophore. Each buccal ganglion gives rise, at its anterior end, to a nerve supplying the lateral muscles of the odontophore, and several small nerves arise from its inner border. A well-marked nerve arises from the posterior border of the ganglion and supplies the posterior muscles of the odontophore; it gives off a branch to the radular sac.

The Visceral Loop.—Tracing this loop from the right pleural ganglion, which is easily exposed, we find that it takes an upward course somewhat towards the left, and soon enters the visceral region, wherein it travels backwards and towards the left, through the salivary glands for a short distance till it reaches the supra-intestinal ganglion (so-called for phylogenetic reasons, because it is on the connective which, in pre-Docoglossan forms, ran across above the gut). This ganglion varies very much in size and distinctness, but from it is always given off a long and slender connective which runs across to the left side above the crop and terminates in a ganglion just beneath the left osphradium. This osphradial ganglion supplies the sense organs near it, and Bouvier has also found a slender nerve arising from it which loses itself near the anterior wall of the pericardium. This, he says, is the vestigial ctenidial nerve, and it has no connection with the osphradium. From this, and from histological considerations, he seems disposed to argue that the osphradium, so-called, is entirely such, and not, as is commonly believed, both osphradium and ctenidial vestige. Resuming our consideration of the visceral loop we find that, from the supra-œsophageal ganglion, it goes backwards and towards the right for a short distance and then runs into the visceral ganglion. This visceral ganglion gives rise to the following chief nerves:—

(*a*) The great visceral nerve which is richly branched and supplies the heart, left kidney, rectum and various viscera.

(*b*) A nerve to the right kidney.

(*c*) Smaller nerves with doubtful distribution.

From the visceral ganglion the loop goes on towards the animal's right side, attaining its extreme position in this direction near where it emerges in front from the visceral mass, thence it goes across beneath the other part of the loop and above the pedal cords to the left pleural ganglion. At the extreme right point a few ganglion cells can be found, and from this point arises a thin and short nerve going to the right osphradium, beneath which there is a small osphradial ganglion. This extreme point would be the proper place for the usual sub-intestinal ganglion, which, therefore, may be represented by the few ganglion cells found there. It is possible that the vanished ganglion is now included in the left pleural ganglion, which is much elongated and partly divided into two. The "sub-intestinal" part of the visceral loop, that is the part next the left pleural ganglion, gives off a couple of slender nerves, one near the pleural ganglion and one further along (fig. 23).

It is characteristic of the Docoglossa that the visceral loop lies entirely to the right of the fore gut, instead of over it and near the right side, as in many other Gastropods. This is in relation to the extra torsion of the fore gut which has taken place in the group.

Sense Organs (figs. 25, 26, 27, 28).—A sub-epidermal plexus of primitive type, with connected sensory cells, still remains in some parts of the body, notably in the sides of the foot of the young animal, but we also have concentrations to form specialised sense organs. These are the cephalic tentacles, the eyes, the otocysts, the osphradia, and the pallial tentacles.

The *Cephalic Tentacles* are a pair of specialised sensory out-growths, situated at the sides of the snout (figs. 4 and 5). They are extremely extensible, and their surface appears corrugated; the apical part is pigmented. At the base of the outer side is a small pit (the eye) lined by deeply pigmented epithelium; this is discussed below.

The tentacle (fig. 25) is covered by a layer of columnar epithelium, the cells of which are long and narrow, with elongated nuclei, and they do not appear to be closely packed when the tentacle is moderately extended. They have a cuticle, which stains yellow with picric acid. There are ordinary epithelial cells, sensory cells and goblet cells. The sub-epithelial layer is a very compact felt-work of fibres, many of which are undoubtedly nervous. Beneath this is a mass of muscle fibres of the usual type, arranged in bundles surrounded by connective tissue. Most of them go from base to tip, and so are longitudinal tentacle-retractors; there are also a few oblique fibres, but no circular muscle occurs. The tentacle nerve goes down the centre, receiving its fibres from the sub-epithelial region, and finally entering the cerebral ganglion, which is at the base of the tentacle. There is a good deal of loose tissue in the tentacle, as might be expected in an organ with such a high degree of contractility.

The animal waves its tentacles as it moves along, the lateral surface near the tip just barely grazing the rock surface over which it is creeping. This lateral surface near the tip is the region of maximum sensitiveness. The tentacles are undoubtedly tactile, and Professor Lloyd Morgan considers them as the organs of the well-known "homing" sense, but, though they may assist in that function, his conclusion seems more than is warranted by evidence. Limpets with the tentacles cut short have "homed" successfully in several cases, and two animals were observed at Granton doing the same, though the entire tentacles had been removed. The pigment on the tentacles is probably of use as a protection, like that on the visceral hump.

The *Eyes* are a pair of organs situated on the outer sides of the swollen bases of the tentacles (figs. 4 and 25), but their shape and position does not seem to be affected by the expansion, contraction and motion of these organs. The eye is really a simple pit, lined by a continuation of the general surface epithelium, part of which has become modified in connection with the sense of light-perception. This modified epithelium is found over a shell-like area, which approaches nearer to the opening of the pit on the lower and outer than on the tentacular and central side (fig. 25). In this modified epithelium we find two kinds of cells (fig. 26):—(1) Elongated sensory cells, with swollen bases, and long clear processes directed towards the surface; and (2) long Pigment cells surrounding and filling up the interspaces between the sensory cells. Each cell consists of (*a*) an internal tapering region, fairly clear, and containing a nucleus in its outer part; (*b*) a broader middle region crowded with minute pigment-granules, and (*c*) a clear outer region. The Pigment is black and resembles that of the mantle.

Nerve fibres, going to the optic nerve, are found beneath this sensory epithelium. The cuticle is well developed over the epithelium of the sensory region. The eye of the Monobranch Docoglossa is more highly developed, its cavity is filled with a jelly-like substance, and the opening is a narrow slit. It is, therefore, almost certain that the eye of *Patella* is degenerate, and this is what might be expected from the conditions of life, since the head remains under the shade of the conical shell.

The *Otocyst*, like the eye, first appears as a depression in the epidermis at the side of the head. With further development it comes to lie far in, and its connection with the exterior is lost. It is found finally just posterior to the pleuro-pedal connective on either side (fig. 23).

The otocysts of the two sides are bound to one another by a fibrous band passing ventral to the pleuro-pedal connectives, and just in front of the pedal ganglia. This band is continued a short distance beyond the otocysts and terminates in the dorsal surface of the foot. It is probably related to the equilibrating function of the otocysts.

The otocyst nerve passes ventral to the pleuro-pedal connective and goes forward between the cerebro-pedal and cerebro-pleural connectives, fusing with the latter not far from the middle of its length. Its fibres enter the cerebral ganglion. The otocyst itself is a cavity lined by ciliated epithelium, the cells of which are in intimate communication with the underlying nerve fibres. The nucleus of these cells is more voluminous than in epithelial cells, and in both *Patella* and *Haliotis* the cells are smaller and longer than in many other forms. The otoliths are small, usually rounded and numerous; the otocyst nerve is hollow, and the otoliths may be found in its cavity some distance away from the main cavity of the otocyst (fig. 27).

The *Osphradia* are patches of brown-pigmented epithelium, situated at the sides of the posterior part of the nuchal cavity, as already stated.

The component cells (fig. 28) are elongated and ciliated, and, beneath them, we find a group of multipolar ganglion cells (osphradial ganglion). In the immediate neighbourhood of the osphradia, and covered by a continuation of this epithelium, are projections, supposed by some to be the last vestiges of the ctenidia of the limpet's ancestors. Their lacunæ are encumbered with corpuscles, and Boutan thinks they have some special glandular function connected with the blood.

The *Pallial Tentacles* round the mantle edge have already been mentioned in general terms, and it has been said that they are of two kinds, large and small, of similar structure. A large tentacle can extend as much as $\frac{1}{8}$ of an inch beyond the mantle edge. The surface of a tentacle presents a number of fine encircling ridges, and, by the action of muscle strands, it can be retracted into a pit, when its surface is thrown into prominent circular folds. The pits for the large tentacles are situated further ventral than those for the small ones (figs. 8 and 24). The tentacle (fig. 8) is covered by columnar epithelium made up of two kinds of cells resting on a basement membrane:—(*a*) Relatively broad goblet cells with a basal nucleus; and (*b*) Sensory cells which are slender, and narrowest in the middle where the nucleus is situated. The outer end bears a number of stiff sensory processes, so that the cell is of the brush type (*pinselzelle*) described by Flemming.

Underneath the basement membrane scattered ganglion cells and nerve fibres can be made out; the latter converge to the axis of the tentacle, where they form a nerve which is connected with the peripheral part of the nervous network of the mantle. At the points of fusion of the tentacle nerves with this network a few ganglion cells are found. Where a tentacle is retracted its nerve is thrown into a coil.

Beneath the epithelium of the tentacle is a fairly continuous sheath of longitudinal muscle fibres, the majority of which are inserted into the tip, though some end at the basement membrane. Most of them collect at the base into two bands which run into the mantle in different directions, those of a laterally placed tentacle being relatively more or less anterior and posterior, though not necessarily in the same horizontal plane. The core of the tentacle is a loose network of connective tissue, muscle fibre, and nerve, and contains large blood spaces.

The above described arrangement of the muscle fibres of the pallial tentacles accords well with our supposition as to their nature, for, better than any other arrangement, it allows of their sweeping over the rock surface, thus enabling the animal to recognise it in some way, and so subserve the "homing" faculty. When the animal "shuffles" round on the scar on returning from an excursion they are in active use.

Circulatory Organs and Cœlom.

Blood System.—As in Molluscs generally, this is to a large extent lacunar, and is greatly developed at the expense of the cœlom, which is reduced to small dimensions. The so-called body-cavity is a hæmocœle, consisting of blood spaces, and the cœlom is reduced to the pericardial cavity, which is, therefore, not a blood space. The blood is a colourless fluid in which float amœboid corpuscles. The parts concerned in blood circulation are the Heart, the Arteries, and the irregular Blood Spaces.

The Heart may be described as a specialised portion of the hæmocœle, which has projected itself into the cœlomic space called the pericardium.

In the primitive *Chiton*, therefore, the feebly differentiated heart is surrounded by cœlomic epithelium, which goes up on either side to the dorsal wall of the pericardium, *i.e.*, the heart is, as it were, suspended from the dorsal wall of the cœlom in an infolding of the lining of that cavity. In *Patella* the heart (ventricle) is also connected with the pericardial roof, but the connection is not so regular and complete as in *Chiton*. In most Gastropods, this connection has disappeared, and it is even possible that it is a secondary consequence of the special reduction of the pericardium in *Patella*.

The *Heart*.—To expose the heart of Patella, carefully make a transverse incision in the front part of the roof of the pericardium. Then remove this roof, first cutting the fibres connecting it with the heart. The heart, thus exposed, will be seen to consist of a thin-walled auricle in front, and a thicker walled ventricle behind (fig. 29).

The auricle receives blood from the pallial gills and related mantle skirt, from the roof of the nuchal cavity, and, perhaps, is directly connected with the reduced left kidney. Blood from the pallial gills and mantle skirt is returned by the great pallial vein into the left front of the auricle, while that from the nuchal cavity is conveyed by a number of small channels opening into the right front part of the auricle. Perhaps among these small channels, which can be very distinctly seen in a fresh uninjured specimen, some bring blood from the left kidney; at any rate, when the auricle is filled by coloured injection the colour is communicated to this kidney.

On opening the auricle by a transverse incision, the large orifice of the pallial vein can be noted, and, to the right of this, a linear series of small apertures from the little channels just mentioned. At the back is the auriculo-ventricular septum, pierced by a transversely oval opening, the edge of which is thickened. The junction of auricle and ventricle is shown by a well-marked constriction, which corresponds to the thickened margin of the auriculo-ventricular septum.

The ventricle stretches right across the pericardium, and its antero-dorsal wall is thicker than the postero-ventral. As has already been said, its dorsal wall is connected by fibres with the roof of the pericardium, along a line going obliquely from right to left (*i.e.*, the long axis of the ventricle), and representing what was the main or antero-posterior axis of the ventricle in ancestral Molluscs.

On opening this chamber of the heart, the interwoven muscle fibres, which form much of its wall, are seen radiating from the thickened margin of the auriculo-ventricular aperture, which is situated near the middle of its antero-dorsal side. The aperture is guarded by two valvular flaps which project into the ventricle cavity.

The main aorta and its posterior branch, the visceral artery, diverge in opposite directions right from the origin, and as they run parallel to, and in close connection with, the ventricle wall, we get an appearance as of a third chamber of the heart. This appearance is emphasised by the fact that the beginnings of the aorta and visceral artery are swollen, and that this pseudo-chamber resembles the ventricle in general characters. The heart of *Patella* was described as three-chambered by Wegmann, who gave the name "Intermediate Chamber" to that which is here called "Ventricle," and the name "Ventricle" to the pseudo-chamber or aortic bulb formed by the swollen arterial bases. Wegmann's determination of parts would make the limpet's heart practically *sui generis*, and would remove the genus very far from the Rhipidoglossa, and even from its nearer allies. The present account, on the other hand, shows the essential similarity between *Patella* and the other Docoglossa in this respect, and agrees with the conclusions of Haller and of Boutan. The aperture between the ventricle and the aortic bulb is guarded by a valvular flap which projects into the cavity of the latter.

Arteries.—The Aorta, of which the origin has just been described, runs to the right end of the pericardium, and then goes on in front of the rectum, soon curving downwards and forwards until it becomes continuous with an anterior sinus, surrounding at least the front part of the radular sac, and enlarging forwards so as to enclose the cushion of the odontophore.

The movements of the odontophore must affect this sinus, especially as it connects with the pedal sinuses and other blood channels. It is in this way that these latter sinuses probably got blood pumped into them. This opinion is greatly strengthened by the observation of the head of living specimens, in which the odontophore can sometimes be seen moving forwards and backwards almost rhythmically. It is interesting to note that a similar and similarly connected sinus exists in *Chiton*, and the pumping work thus done outside the heart may be correlated with the feeble muscularity of the ventricle in so many of the lower Molluscan forms. The existence of arterial branches of the aorta, other than the posterior or visceral artery, is doubtful, though possibly one goes into the salivary glands.

The Visceral Artery seems to branch almost immediately after leaving the left posterior corner of the pericardium, one branch certainly goes to the gonad region and the other also seems to enter the visceral hump.

The course of the arteries cannot be traced far from the pericardium, the greater part of the blood system being lucunar, *i.e.*, consists of spaces which have not a definite epithelial lining.

Lacunæ and Sinuses (Blood Spaces).—Blood from the Anterior Aorta goes into the great anterior sinus surrounding the radular sac and odontophore cushion. Thence it proceeds into

(*a*) The Pedal Sinuses (fig. 8*a*).—These are fairly distinct spaces running back through the foot on either side just internal to the nerve cord. The anterior sinus opens into these near the pedal ganglia.

(*b*) Spaces in the visceral hump, from that part of the sinus which surrounds the radula.

The foot is, therefore, supplied from the anterior aorta *viâ* the anterior sinus, while the visceral hump is supplied partly in the same way and partly by the posterior artery. The shell muscle seems to be furnished with blood from the pedal sinuses. The impure blood from the foot and that from the visceral hump goes to the perivisceral sinus which, as its name implies, surrounds the viscera. From this sinus some of the blood goes to the blood spaces in the trabeculæ, etc., of the large right kidney, and, more doubtfully, to those of the left kidney. For this reason the perivisceral sinus and large kidney are about co-extensive. Practically the whole of the blood from the perivisceral sinus, including that which has traversed the kidney trabeculæ, etc., ultimately finds its way out to the mantle. Some of it goes to the nuchal mantle, while the remainder reaches the mantle skirt by way of channels running between the fasciculi of the shell muscle.

Before describing the oxygenation of the blood, it is convenient to describe the circulation in the head, in the nuchal mantle, and in the left kidney. The main channels in the head region are the parts and ramifications of the anterior sinus, *i.e.*, spaces below the lining epithelium of the gut, and particularly of the odontophore. From this space, blood seems to go all over the head around the body wall. The inner lips, which are puckerings of this gut epithelium and subjacent tissue, contain each a blood space so that their opening and closing may be brought about in part by changes in blood pressure. It is impossible to say whether the circulation in the head is a loop system, or whether it is merely an enlargement of the great blood space around the odontophore—probably both interpretations are to some extent correct, and, if so, the foot is partly supplied with blood that has already been around the head. Possibly, however, the blood in the head becomes re-purified where it runs near the surface in places covered by delicate skin (*e.g.*, tentacles, etc.).

From the anterior end of the perivisceral sinus some blood goes into a network of spaces in the nuchal mantle, and these lead off ultimately into the auricle through the linear series of small apertures seen on opening the latter. This blood must be partly oxygenated. Blood channels from the mantle, in more primitive forms, probably opened, as they do in the Rhipidoglossa, into the efferent ctenidial veins, but as these latter disappeared they have become directly connected with the auricle, and have undergone compensating development.

The blood reaching the left kidney, in a more primitive form, would have gone out to the corresponding ctenidium for oxygenation, returning thence by the left branchial vein to the left auricle. A change has necessarily had to follow the disappearance of the left ctenidium, and now in *Patella* there is some doubt as to the circulatory arrangements of the left kidney. Possibly it receives blood from the perivisceral sinus and passes it on almost direct to the auricle. If this is not the case, this organ must be in direct dependence on the auricle for its blood supply—a condition which its homologue in *Haliotis* seems to have attained. The circulatory arrangements of the left kidney, even of the primitive *Patella*, show how far this organ has departed from the ordinary condition of a kidney among the lower Gastropods.

The blood which does not reach the heart through the minute channels of the nuchal mantle, or *viâ* the left kidney, goes out to the mantle skirt and pallial gills through channels running between the fasciculi of the shell muscle, and, afterwards, in the substance of the mantle skirt. After oxygenation in the pallial gills and mantle edge, blood is returned to the large pallial vein by small veinlets projecting on the ventral surface of the mantle skirt (fig. 7). Those from the edge (Vl. fig. 7) unite with those from the gills (G.V. fig. 7), and the channels thus formed turn outwards to open into the large pallial vein. The veinlets from the mantle edge can, therefore, be seen at intervals crossing over the ventral surface of this large pallial vein, which runs completely round the mantle skirt just external to the attachment of the pallial gills (fig. 3). The completeness of the circle is broken at one point directly anterior to the left front end of the shell muscle; here the two sides of the vein bend inwards and fuse into one trunk which runs along the inner side of the shell muscle to the left front corner of the pericardium.

It must be remembered that, though the name "vein" is applied to them, none of the blood channels in the mantle are true vessels, even the great pallial vein being of the nature of a lacuna.

Cœlomic System.—The extensive development of the blood system has entailed a corresponding reduction of the cœlom, of which there remains practically nothing except the pericardium. The form and position of the pericardium have already been described, and it only remains to say now that the pericardial gland seems to be absent. The pericardium communicates with the large right kidney, and, as we can positively state, with the small left one as well, but this matter will be discussed later in dealing with the excretory organs.

Haller described a pair of cœlomic cavities between the visceral hump and the foot, but Pelseneer does not confirm this, and our results tend to the conclusion that the only epithelium-lined cavity in this region is that of the large kidney.

The cavity of the gonad, visible only in a very young specimen in which the sex products have not yet been much differentiated, is necessarily a remnant of the cœlom. It becomes practically obliterated at a later stage.

Respiratory Organs.

With the specialisation of the right side of the branchial chamber as an excurrent channel for waste products, the right ctenidium, we may suppose, disappeared at an early stage in the descent of the Docoglossa. In the less modified members of this group, *Acmœa,* etc., the work of respiration is, therefore, performed mainly by the surviving left gill, but in part also by the mantle skirt, which has increased in importance as the shell became more cup-like, and its projecting edge spread farther out. The mantle skirt in these Monobranch forms already shows a tendency to the formation of a series of transverse ridges, constituting incipient secondary or mantle gills (*Lottia* and *Scurria*). In *Patella* both primary gills are reduced, being represented only by vestiges (fig. 4). The nuchal chamber, in which these vestiges are contained, is equivalent to the branchial chamber of a *Pleurotomaria, Fissurella,* or *Acmœa* in a reduced condition. This chamber, however, still plays a subordinate part in respiration, although that function is mainly effected by the circlet of pallial gills, which have now attained a high degree of development.

It will be convenient to give details under three headings:—Nuchal Roof, Vestigial Ctenidia, Pallial Gills.

The *Roof of the Nuchal Chamber* has already been mentioned, and it has been stated to be permeated by a network of blood channels; its histological structure has also been discussed. The abundance of blood channels, the general structure, and the fact that blood goes direct from it to the auricle makes it probable that this tissue acts as a respiratory organ. Probably the movements of the head, nuchal floor, etc., enable the cavity to function as an imperfect sort of lung when the animal is left uncovered by the tide. Individuals living far up the shore are uncovered for the greater part of the time, and such a specialisation would undoubtedly be advantageous.

The supposed *Ctenidial Vestiges* are probably entirely functionless, but there is a large osphradium, with underlying osphradial ganglion, in connection with each. It is generally thought that the function of an osphradium is the qualitative testing of the respiratory medium, and the retention of these organs in *Patella* is an argument in favour of the respiratory activity of the nuchal chamber. The osphradium has been described in the account of the sense organs, where it is also stated that Bouvier does not accept as such what are here described as ctenidial vestiges. The vestige is a mass of connective tissue containing blood spaces, and situated near the osphradium; these blood spaces contain numerous corpuscles, and Boutan remarks that the mass resembles a lymph gland.

The *Secondary* or *Pallial Gills* have already been mentioned. Each gill is triangular in form, with the base attached to the mantle. The inner side is curved and runs from the mantle to the outwardly projecting apex, and, from this apex, the third side runs straight up to the mantle (fig. 8*a*). A pallial gill is merely a downgrowth from the mantle skirt, and both, therefore, have an essentially similar structure. It is covered by epithelium, with many cells ciliated, some glandular, and some sensory (fig. 9*b*); beneath this is a nerve plexus, with a few multipolar ganglion cells (fig. 9*b*). Within this we find a comparatively small amount of muscle fibre and other tissue enclosing a large blood space subdivided by fibrous trabeculæ (fig. 9*a*). Blood enters the inner border of the gill and leaves from its outer border, and in these two positions we, therefore, find rather large and distinct blood spaces.

We may now shortly summarise what has been said concerning respiration and the circulation of the blood in the mantle.

Blood comes in from lacunæ running between the fasciculi of the shell muscle; it is then distributed both to the pallial gills (through a blood channel running ventrally and reaching the inner border of the gill) and to the mantle proper (through lacunæ running further dorsally). In the latter set of lacunæ, the blood seems mostly to reach the mantle edge whence it returns through channels which project like veinlets on the ventral surface of the mantle. In the former set of lacunæ it is distributed over the gills and is then collected into ventrally placed efferent lacunæ (fig. 7), which leave the outer border of the gill and join the veinlets from the mantle edge. The united sinus opens into the inner side of the great pallial vein (fig. 7). Though the pallial gills and the nuchal roof are the only distinctly respiratory organs, it must not be supposed that they are the only places in which blood is oxygenated. The skin in several parts seems to be sufficiently delicate to allow the necessary diffusion to proceed; such places, for example, are the surface of the tentacles, of the inner lips, etc.

Excretory Organs.

Two kidneys are present, of which the right is much the larger.

The much-reduced *Left Kidney* (see figs. 4, 5, 8, 31) is a small compact sac with only a limited excretory activity. The wall of this kidney is thin where it abuts on the rectum. but is much thickened where it adjoins the pericardium. It possesses renal epithelium like that of the right kidney, and the amount of excretory matter visible is fairly large. The consensus of opinion is in favour of its possessing a reno-pericardial pore, a conclusion which our preparations confirm. The thickened wall between the left kidney and the pericardium is a heterogeneous mass made up of a few muscle fibres and connective tissue, with occasional granular cells of lymphatic function. In this mass are numerous cavities which are blood lacunæ.

The *Right Kidney,* which seems to be the main excretory organ throughout the Gastropod series, has, in *Patella,* been flattened out and spread around the visceral hump, in correlation and connection with the great perivisceral blood sinus. It is a large structure made up of several lobes (figs. 4, 5, 8, 31):—

(*a*) An anterior dorsal lobe, extending superficially over the front of the visceral hump behind the pericardium and rectum.

(*b*) A posterior or perivisceral lobe, extending around the visceral hump backwards along the right side, and then a fair distance forwards along the left. In very old limpets (*a*) and (*b*) are united distally.

(*c*) A ventral lobe, extending on the ventral surface of about the right half of the visceral hump and connected laterally with (*b*).

(*d*) A sub-rectal lobe stretching beneath the rectum and the back part of the left kidney, and with its apical portion contiguous to the pericardium.

When coloured by excretory matter or by injection, the outlines of the dorsal parts of the kidney become visible, making it appear to be a much branched arborescent gland. On opening, this impression is corrected, for we find the structure characteristic of the excretory organs of Mollusca. It is essentially a sac lined by renal epithelium, but the space is much obstructed by the growth across it of subjacent tissue, forming pillars over which the renal epithelium is, of course, continued. These pillars or trabeculæ contain extensions of the part of the perivisceral sinus in contact with the kidney (see fig. 32*a*). They increase the excretory surface, and in this way add to the efficiency of the organ. It was long supposed that the blood channels actually opened into the kidney, and that the blood, in this way, received water; but this idea is now quite discredited, and we know that the renal epithelium forms a boundary everywhere between the blood sinus and the kidney cavity. This renal epithelium consists of a single layer of cells of variable size. Many of them are ciliated, especially when young. As they grow older, these cells amass concretions, some developing a number of small ones, other a few larger ones (fig. 32*b*). These concretions contain, mainly, nitrogenous waste, and are dark brownish green in colour. The relation of the kidney to the perivisceral blood sinus is that typical for Molluscan kidneys generally, the renal epithelium forming a much complicated partition between a blood space on the one hand, and, on the other, a cavity opening to the exterior. The excretory papillæ of the kidneys have a small central canal lined by ciliated epithelium, outside which is a fairly strong ring of circular muscle. The blood supply of the kidneys has already been spoken of in the account of the circulation, to which reference should be made.

The pericardial communication of this right kidney has often been discussed, the difficulty of observation having led to the enunciation of conflicting opinions by different workers. It is generally admitted that the reno-pericardial canal opens into the sub-rectal lobe of the kidney, but the exact position of this opening, and the length of the canal, are subjects of dispute. Cunningham makes the canal open into the dorsal surface of the sub-rectal lobe some distance to the left of the rectum, while Goodrich and Pelseneer find the opening on the ventral surface of that lobe practically ventral to the rectum. Our results (fig. 31) support the latter view, and we find that the long canal opens into the extreme right end of the pericardium. Most of our sections differ somewhat from those of Pelseneer and Goodrich as regards the space relations of kidneys, pericardium and nuchal cavity, but we think these relations vary a good deal in different specimens, and also change somewhat with the age of the individual.

Reproductive Organs.

The gonad occupies the ventral face of the left side of the visceral mass (figs. 6, 8) in both sexes. It varies very much in size at different seasons. In a very young form it is practically a pouch, the cavity of which is cœlomic. This cavity is lined by germinal epithelium, which, with its underlying tissue, grows in as folds, some of which unite into trabeculæ (fig. 33*a*), thus converting the pouch into a mass of sex cells covering the connective basis. As the gland grows in each season towards maturity it pushes forwards, sometimes as far as the level of the œsophageal pouches, and often extends across the median line towards the right side (fig. 8). At the time of complete maturity the ova are surrounded by a tough coat, which possesses a micropylar opening. The ovum contains numerous yolk spherules (fig. 33*b*). The sperms (figs. 34) are very minute and consist of head and tail as usual.

The gonad expels its products by rupture into the cavity of the right kidney, and they thus make their way to the exterior. The gland seems peculiarly liable to overgrowth, and, among specimens collected in autumn on the Welsh coast, various ruptures can frequently be noticed, sometimes between the shell muscle and the foot, sometimes above the shell muscle, though this latter does not seem to be of any advantage for the expulsion of sex products. The season of sexual maturity is the autumn; Boutan finds it to be about September at Roscoff; at Aberystwyth we think it is somewhat later. A few limpets have been found by Gemmill with male and female regions in the gonad, and he also notes that the percentage of the two sexes do not depend on tidal level.

Though the gonad is situated on the animal's left side it must not, therefore, be supposed to be the (post-torsional) left member of an ancestral pair, for there have been such changes in connection with the consolidation of the hump that the present position cannot be taken as a guide. The evidence rather points to the view that we have here the (post-torsional) right member of the ancestral pair, for:—

(1) In all other classes of Gastropods the (post-torsional) right gonad, and, in Cephalopods, the one corresponding to this (*i.e.*, the left), is the one which survives.

(2) The blood supply of the gonad (from the posterior artery) is identical with that of the gonad of other primitive Gastropods, in which that organ distinctly belongs to the post-torsional right side. Possibly, however, the other member of the ancestral pre-torsional pair of gonads has fused with it.

(3) The sex products are expelled into the right kidney, and, perhaps, the extension of this organ on the ventral surface of the hump is, in part, an attempt to preserve its ancient connection with the gonad, an attempt which, as we have seen, is partially unsuccessful.

It is, however, not impossible that the apparently single gonad has arisen from the fusion of the primitively distinct pair.

Development.

(See figs. 35 to 42).

The ovum has already been described as a small globular body covered by a tough coat, which is incomplete at one spot—the micropyle. The sex products are extruded into the surrounding sea water and fertilization occurs in a haphazard fashion, the sperms entering *viâ* the micropyle. Sperms seem to make their way occasionally into the females, as ciliated embryos are occasionally found which have not yet been extruded. It is not impossible that hermaphroditism, to a very small extent, may be rather more common than is supposed, and this kind of variation would seem to be advantageous to the animal, though self-fertilization has its drawbacks. Fertilization may be obtained artificially by injecting the sex products of one kind into the nuchal cavity of a mature member of the other sex, or by mixing both kinds of sex products in a small volume of sea water. By observation of artificially fertilized ova, Patten has been able to follow the early stages of development.

The fertilized ovum segments into two, and then into four fairly equal cells. Subsequent divisions are markedly unequal, giving rise to numerous small cells (future ectoderm), and, less rapidly, to a few larger cells (future endoderm and mesoderm). The "Gastrula" stage is initiated by growth of the smaller (ectoderm) cells over the large cells, *i.e.*, by epiboly. The blastopore is the spot over which the small cells do not spread. By differential growth a blastocœle is now formed, into which the inner ends of the large cells grow. These cells bud off smaller ones towards the blastocœle, and from one of these are developed the two primary mesoderm cells.

The ectoderm is mostly ciliated at first, but two adjacent transverse rows of cells soon develop larger and more conspicuous cilia, thus forming two (pre-blastoporal) ciliated rings around the embryo. These together form the "Prototroch," the first rudiment of the "Velum." The apical cells of the embryo also develop very long cilia, and those around them shorter but still conspicuous ones. These ciliated cells lengthen and sink, forming a fairly flat apical plate. At the opposite pole of the embryo two ectoderm cells increase in size and also bear cilia. These are called the anal ciliated cells. Another group of ectoderm cells, posterior to the Prototroch and on the dorsal side, become depressed and lengthened. These form the shell gland which increases in extent especially at the back, making this part of the surface of the embryo convex, and shifting the ventrally-placed blastopore relatively forwards. Meanwhile the blastopore changes its relative position, becoming U-shaped and then slit-like. In the position of its most anterior portion, there occurs an insinking of ectoderm, which pushes this part of the blastopore inwards, and its ultimate destiny is to form the opening from the (ectodermic) stomodœum into the (endodermic) mesenteron. The remainder of the blastopore has closed. On either side of the blastopore in its slit-like stage we find one of the mesoderm cells, which divides and gives rise to a pair of rounded elevations. These two elevations are the rudiments of the foot.

At this stage the larva is practically a trochosphere. Its præoral region is large and possesses a well-developed prototroch and an apical plate. Near the apical plate there appear two small ciliated elevations each consisting of a single cell with cilia. The shell gland secretes a shell which becomes more and more convex outwards, attaining a rounded cup-shape. The originally solid mass of endoderm becomes hollowed out and arranges itself as the lining of the midgut. It gives off a diverticulum postero-ventrally, which ultimately opens to the exterior forming the rectum. The fore-gut gives off a diverticulum ventrally, which is the rudiment of the radular sac.

The ectoderm thickens and projects along a band just external to the shell margin, and this is the first trace of the mantle skirt. The anal diverticulum reaches the ectoderm ventral to this, and between anus and mouth we now find the well-marked pair of foot rudiments. A pair of depressions occur at the sides of the mouth and grow inwards along the sides of the foot, becoming closed sacs and forming the otocysts.

As the shell and foot continue to grow, the anal diverticulum and the rudiment of the branchial cavity become confined between them, and we then observe their migration from the postero-ventral position, along the animal's right side, ventral to the mantle skirt, up to an antero-dorsal position behind the prototroch, which has now grown out and become the "Velum," the differentiated locomotor organ of the larva. The larva is bound to its cap-shaped shell at first by a strand of tissue inserted into the apex of the cap. Later on, Boutan has observed in *Acmæa* the development of a pair of antero-lateral muscular strands inserted near the shell margin and functionally replacing the apical strand. This pair of muscles spreads backwards, and ultimately form the horse-shoe shell muscle of the adult.

The shell now grows chiefly by additions to its posterior border so that its mouth is much widened and the apex comes to lie relatively far forwards. The apical portion, which may show the beginnings of development of a symmetrical spire, breaks off and the hole is closed by a secretion of nacreous material. The next stage known has the foot broadened into the adhesive sole of the adult, the shell muscle horse-shoe shaped, and the shell conical. This stage possesses a glandular streak on each side of the foot, homologous with that found in the adult of *Nacella* and its allies; it disappears later.

In further growth of the shell, the anterior margin seems to share more largely, so the apex subsequently undergoes relative motion towards the back. This is more marked in limpets which live in positions much exposed to the action of the waves, such limpet-shells being lower cones than those in which the growth is more equal.

Conclusions.

Of the features which have now been described in *Patella*, the following characterise the Cyclobranchs, the specialised group of the Docoglossa to which our type belongs:—

(1) The highly differentiated crop placed so as to form a

curve with concavity towards the right anterior corner of the visceral mass.

(2) The intestinal coil (Int. 2) placed on the dorsal surface of the visceral mass. Its position varies in different forms, being often much further to the left than it is in the limpet.

(3) The presence of three uncini and nearly always, at any rate, three lateral teeth on each side of each row of teeth in the radula.

(4) The strong odontophore with its squarish front, its highly differentiated transverse muscles, and its numerous cartilages (more than the usual two pairs).

(5) The large development of buccal glandular tissue.

(6) The pseudo-chamber (or aortic bulb) formed by the varying amount of swelling of the basis of the aorta and posterior artery.

(7) The practically transverse posterior boundary of the triangular pericardium.

(8) The absence of a ctenidium, the smallness of the branchial (nuchal) cavity, and the occurrence of a circle of pallial gills. This circle is incomplete above the head in some Cyclobranchs (*Helcion*), and in others the gills in that position are small (*Nacella*).

(9) The presence of a lateral or epipodial streak. It has not been found in *Helcion* and its allies, and it disappears in the adult *Patella*, but persists throughout life in *Nacella.* It is not known in any of the more primitive Docoglossa (Monobranchs and Lepetidæ).

(10) The specially degenerate eye.

(11) The numerous differentiated large and small pallial tentacles.

The following features characterise the whole group of the Docoglossa :—

(12) The apex of the simple conical shell is typically bent

over so that it points forwards and is usually placed in front of the middle of the shell. In adult Cyclobranchs growth of the front edge of the shell often makes these features less distinctly marked.

(13) The long raking radula with a limited number of specialised clawed teeth. The median tooth is not specially differentiated (except in some Lepetidæ), and is typically reduced and often absent.

(14) The disposition of the parts of the gut shown in Fig. 10*a*, except as regards details mentioned in (1) above. This is not quite constant throughout the group, but is found in several types and the disposition of the stomach-coil is quite characteristic.

(15) The position of the visceral loop of the nervous system well to the right of the median line.

(16) The practically triangular pericardium completely filled by the heart and situated at the left anterior corner of the dorsal surface of the visceral hump.

(17) The superficial extension of the right kidney (almost characteristic) and the retention of a certain amount of functional excretory tissue by the tiny left kidney.

The following features show that *Patella* and the Docoglossa rank among the lower Gastropods :—

(19) The presence of a horse-shoe muscle derived, as the development of *Acmæa* shows, from the backward extension of a pair of laterally placed muscles.

(20) The retention of external symmetry throughout the development, as far as is known.

(21) The feeble concentration of ganglia in the nervous system and the anastomosing commissures between the pedal cords.

(22) The presence of a complete labial commissure and the form both of this and of the buccal nervous system.

(23) The possession of a pair of osphradia placed right and left in the nuchal cavity.

(24) The possession of two kidneys right and left, the left still possessing some excretory tissue.

(25) The extrusion of the sexual products through the right kidney and the absence of all accessory sexual organs.

Of those characters which are peculiar to the Docoglossa amongst Gastropods—

No. (12) is an adaptation to the adhesive habit, while (14), (15), and (17) are consequences of the consolidation of the visceral hump involved in the development of (12).

No. (16) is due to the disappearance of the right ctenidium and the subsequent shifting of the heart to the left side so that it might lie behind the remaining ctenidium (which has also disappeared in *Patella*).

No. (13) is a specialisation enabling the animal to gather its food by scraping the rock or other surface over which it creeps.

Among the Cyclobranchs:—

Nos. (1) and (5) are specialisations to overcome the difficulty of digestion of the tough food.

Nos. (2) and (7) are special consequences of the further compression of the parts of the visceral hump among these forms.

No. (3) is an undoubted characteristic, but is not easy to understand.

No. (4) is an adaptation to the habit of extruding the tip of the odontophore for raking purposes and to the consequent need of a flat dorsal surface, a broad front. and facilities for adjustment.

The reduction of the pericardium has led to the development of No. (6), this arrangement promoting the regular and unimpeded circulation of the blood.

No. (8) is the feature which gives the group of "Cyclobranchiata" its name. The ctenidium in a fairly deep branchial cavity could not be kept well rinsed among sluggish forms often left uncovered by the tide. The ctenidium, therefore, became inefficient and has disappeared, the pallial gills being a new and compensating development.

No. (9) is an interesting feature not easy to account for. Perhaps the glandular secretion improves the animal's power of holding on and helps it to withstand desiccation in the exposed spots which these forms typically inhabit.

No. (10) is a consequence of having the head always under the shadow of the shell.

No. (11) is a specialisation which helps the animal to obtain a topographical acquaintance with its immediate neighbourhood.

It will thus be seen that the Docoglossa, though undoubtedly correctly included among the lower Gastropods, are yet specialised on lines of their own in connection with their adoption of the habit of adhering to exposed surfaces and making limited excursions for the purpose of raking up food.

They cannot be said to be directly and closely related to any of the other primitive Prosobranchs, the connection in each case being due to descent from a not very remote common ancestor. *Pleurotomaria* and the Trochidæ have specialised on quite other lines as regards the shell, foot, and shell muscle, and this is true also of *Haliotis*, which has adapted itself to creeping about in chinks and confined spaces. The great contrasts in the respiratory systems and in the general disposition of organs show the distance that separates these forms phylogenetically. The Fissurellidæ have also evolved on quite other lines though they have a shell muscle and visceral hump closely resembling that of the Docoglossa externally. The most striking contrasts are the presence of a pair of ctenidia in the Fissurellidæ and the shortening of the path of the excurrent stream of the branchial cavity in these forms by the deepening of the slit or its conversion into a hole at or near the apex of the conical shell.

Scissurella is certainly one of the most primitive Prosobranchs known and may be more nearly related to the Docoglossa than are the other groups named, but even in this form the left kidney is specialised in the same way as in *Pleurotomaria*, etc.

The fossil Bellerophontidæ were very primitive Gastropods, though we cannot know enough about them to say much of their relationships. It is, however, possible to conceive of the evolution of the Docoglossa from forms something like them, the symmetrical spire undergoing relative reduction as the posterior margin of the peristome grew out.

Explanation of the Plates.

Reference Letters used in the Plates.

Note.—The letters d—n in Figs. 13*b* and 13*c* refer to the minute muscles of the odontophore, and are not included here.

A. = Thin brown external layer of shell.
A.C. = Anterior cartilage of odontophore.
A.-D. Lobe = Antero-dorsal lobe of right kidney.
A.-L.C. = Antero-lateral cartilage of odontophore.
An. C. = Anal cells.
Ant. Ao. = Anterior aorta.
Ap. D. = Apical disc.
B. = Thick middle layer of shell.
(*a*) Outer part traversed by branching canals.
(*b*) Clear inner part.
B.C. = Buccal cavity.
Bp. = Blastopore.
Buc. = Buccal commissure.
Buc.D. = Duct of buccal gland.
Buc.G. = Buccal ganglion.
Buc.Gl. = Buccal glands.
C. = Internal laminated layer of shell.
Cer. = Cerebral ganglion.
Cer.C. = Cerebral commissure.
Cil.R. = Pre-blastoporal ciliated ring which becomes prototroch.
C.-Ped. = Cerebro-pedal connective.
C.-Pl. = Cerebro-pleural connective.
D.F.G. = Dorsal fold of gullet wall.
D.H.P. = Duct of hepato-pancreas.
D.P. = Dorsal palatal plate.
D.Pal.Gl. = Dorsal pallial gland-tissue.
Ect. = Ectoderm.
E.-M. = Endo-mesoderm.
Ep. F. = Epithelial fold.
Fl. = Flap of lateral ("epipodial") streak.
F.R. = Foot rudiments (mesoblastic).
G.-l. = Gland tubules of lateral ("epipodial") streak.
G.M.T. = Greater pallial tentacle.
G.M.V. = Great pallial vein.
Go. = Gonad.
G.V. = Veinlet from pallial gill.
H. = Head.
H.-P. = Hepato-pancreas.

Int. = Intestine (the coils are numbered in Figs. 10*a* and *b*).

I.L. = Inner lip (only a line is shewn as neither lip comes in median section).

K.C. = Kidney cavity.

Lab. = Labial commissure.

Lat.St. = Lateral ("epipodial") streak.

L. Au. = (Morphologically left) auricle.

L.K. = Left kidney.

L.K.Ap. = External aperture of left kidney.

L.M.T. = Lesser mantle tentacle.

L.Osph.G. = Left osphradial ganglion.

M. = Mantle or pallium.

Mcp. = Micropyle.

Mesen = Mesenteron (endodermic).

Meso. = Foot rudiments (mesodermic).

M.Gang.C. = Multipolar ganglion cell.

M.T. = Pallial tentacle.

Mth. = Mouth.

M.T.N. = Nerve of pallial tentacle.

N.C. = Nuchal cavity.

N.R. = Nuchal roof.

N.R.V. = Veinlets from nuchal roof.

Odont.C. = Odontophore cushion.

Oes.P. = Oesophageal pouch.

O.L. = Outer lip.

Op.N. = Optic nerve.

Os. = Osphradium.

Os.E. = Osphradial epithelium.

Osph. G. = Osphradial ganglion.

Ot. = Otocyst.

Ot.N. = Nerve of otocyst.

P. = Pericardium.

Pal.Gl. = Pallial gland-tissue.

Pal.M. = Pallial muscle.

Pal.N. = Nerve in mantle tissue.

Pap. = Ridged papella or "licker."

Pap.Cr.F. = Papillæ of internal edge of transverse crop folds.

P.C. = Posterior cartilage of odontophore.

P.Cell. = Pigment cell of eye.

Ped. = Pedal nerve cord.

Ped.Anas. = Pedal anastomosis.

Ped.S. = Pedal sinus.

Pig.Bd. = Pigment band.

Pl. = Pleural ganglion.

Pl.Ped. = Pleuro-pedal connective.

Post.A. = Posterior artery.

P.Pal.N. = Posterior pallial nerve.

P.p.b.c. = Post palatal buccal cavity.

Pr.Tr. = Prototroch.

P.-V.Lobe. = Perivisceral lobe of right kidney.

P.Z. = Pigment zone of pigment cell of eye.

R. = Rectum.

Rad. = Radula.

Rect. = Rectal evagination of mid-gut.

R.G. = Rudimentary gill (ctenidium).

R.K. = Right kidney.

R.K.Ap. = External aperture of right kidney.

R.Osph.G. = Right osphradial ganglion.

R.R.P. = Renal aperture of reno-pericardial canal of right kidney.
R.S. = Radular sac.
S.C. = Sense cell of eye.
Sec.F.Cr. = Radial secondary folds on the transverse crop folds.
Sec.G. = Secondary or pallial gills.
S.L.P. = Sub-lingual pouch.
S.M. = Shell muscle.
S.-R. Lobe. = Sub-rectal lobe of right kidney.
S.R.M. = Sub-radular membrane.
St. = Stomach.
St.Gr. = Groove in stomach-wall.
Sub-Ep.N.L. = Sub-epithelial nervous layer.
Sub-Oes.C. = Sub-oesophageal connective of visceral loop.
Sup.-Int. = Supra - intestinal ganglion of visceral loop.
S.Z. = Sensory zone of mantle epithelium.
T. = Tentacle.
T.N. = Tentacular nerve.
V. Visceral loop.
Vac.E. = Vacuolated epithelium beneath lateral streak.
V.F.G. = Ventral fold of gullet.
V.G. = Visceral ganglion.
V.H. = Visceral hump.
V.L.C. = Ventro-lateral cartilage of the odontophore.
V.-l.F. = Ventro-lateral folds of wall of rectum.
Vl. = Veinlet from mantle edge.
V.-Lobe. = Ventral lobe of right kidney.
Vn. = Ventricle.
V.St. = Valve hindering flow of secretion of hepato-pancreas into anterior part of gut.
X is the point of connection between Int. 1 (Fig. 10*a*) and Int. 2 (Fig. 10*b*).
Y. is the point at which the stomach folds on itself (Fig. 10*a*).
Z. is the anastomosis between the posterior pallial nerves of the two sides.

The terms *right* and *left* are always used to signify post-torsional relations unless otherwise specified.

Plate I.

Fig. 1. Extreme forms of shell of *Patella vulgata*. From specimens collected in the Gouliot Caves, Sark.

Fig. 2. Section through the shell. *A* Thin brown external layer. *B* Thick middle layer: (*a*) outer part traversed by branching canals; (*b*) clear inner part. *C* Internal laminated layer. × 15.

Fig. 3. The animal in its shell—Ventral surface. *H.* = Head.

Fig. 4. Dorsal view to show positions of organs. The pigment layer of the mantle has been rubbed off

and the nuchal roof removed. *M.T.* = Pallial tentacle. *Os.* = Osphradium. × $1\frac{1}{4}$.

Fig. 5. The animal seen from the left anterior point of view (diagrammatic and based upon published figures). The nuchal roof has been removed. × $2\frac{1}{2}$.

Fig. 6. Diagrammatic sagittal section—most of the blood sinuses, also the kidneys and nerves are omitted for the sake of clearness. *B.C.* = Buccal cavity. *D.P.* = Dorsal palatal plate. *I.L.* = Inner lip (not in median section). *O.L.* = Outer lip. *N.R.* = Nuchal roof. *Oes.P.* = Tissue of oesophageal pouch. *Pap.* = Ridged papilla. *S.L.P.* = Sublingual pouch. × $2\frac{1}{2}$.

Fig. 7. A small portion of the ventral surface of the mantle showing the circulatory arrangements. *Vl.* = Veinlet from mantle edge. *G.V.* = Veinlet from pallial gill. × 10.

Plate II.

Fig. 8*a*. Diagrammatic transverse section of a very young specimen to show the lateral streak, the arrangement of fibres in the foot, the relations of the kidney cavity, the structure of the mantle skirt, × 35. *D.Pal.Gl.* = Dorsal pallial gland-tissue. *Ep.F.* = Epithelial fold. *Fl.* = Flap of Lateral ("Epipodial") streak. *Gl.* = Gland tubules of Lateral ("Epipodial") streak. *Lat.St.* = Lateral ("Epipodial") streak. *Pal.Gl.* = Pallial gland-tissue. *Pal.M.* = Pallial muscle. *Pal.N.* = Nerve in mantle tissue. *Ped.S.* = Pedal sinus. *Sub-Ep.N.L.* = Sub-epithelial nervous plexus. *S.Z.* = Sensory zone of mantle epithelium. *Vac.E.* = Vacuolated epithelium beneath the lateral streak.

Fig. 8*b*. Epithelium of one of the folds of a pallial tentacle in cross-section (after Haller). Highly magnified.

Fig. 9*a*. Horizontal section of a pallial gill. × 30.

Fig. 9*b*. Part of the sub-epithelial nerve plexus of a pallial gill (after Haller), showing connection with sense cell and multipolar ganglion cell (*M. Gang. C.*). Highly magnified.

Fig. 10. The alimentary canal of Patella. See description, page 212. For the sake of clearness this is represented in two parts, the first three coils are shown in Fig. 10*a* and the third (Int. 1) connects at × with the fourth (Int. 2) in Fig. 10*b*. *Y* in Fig. 10*a* is the point at which the stomach folds on itself. The coils of intestine are labelled Int. 1, Int. 2, etc. × 1.

Fig. 11. Dorsal palatal plate. × 10.

Fig. 12. Diagram showing the radular sac, etc. *Rad.* = Radula. × 3.

Fig. 13*a*. Dorsal view of the odontophoral cartilages. × 3.

Fig. 13*b*. Ventral view of odontophoral cartilages and muscles. See p. 223 for description. Some muscles are supposed to have been removed. Somewhat diagrammatic. × 3.

Fig. 13*c*. The inturned (median) surface of left half of odontophore cushion. Some muscles have been removed. × 3.

Fig. 14. One row of teeth from the radula. × 25.

Fig. 15. Diagrammatic transverse section of the gullet to show the positions, etc., of the ducts of the buccal glands. × 15.

Fig. 16. Diagram of the gullet and buccal glands in a specimen which had the glands unusually well marked off from one another. × 3.

Fig. 17. Section of a lobule of the hepato-pancreas (after Haller). Highly magnified.

Fig. 18. Surface of one of the transverse folds of the crop. *Pap.Cr.F.* = Papillæ of internal edge of transverse

crop folds. *Sec.F.Cr.* = Radial secondary folds on the transverse crop folds. × 15.

Fig. 19. The bend of the stomach (*Y* in fig. 10*a*) showing the opening of the duct of the hepato-pancreas (*D.H.P.*). *St.Gr.* = Groove in stomach wall. *V.St.* = Valve hindering back flow of the secretion of the hepato-pancreas. × 3.

Fig. 20. Transverse section of ridges and groove in stomach wall of a young specimen (after Haller). Highly magnified.

Plate III.

Fig. 21. Transverse section across the rectal papilla. × 20.

Fig. 22*a*—*f*. A series of transverse sections of gullet and crop (the posterior faces of the sections are drawn) showing the migration of the points of attachment of the longitudinal folds (*D.F.G.* and *V.F.G.*) through an angular distance of over 270°. *D.F.G.* = Dorsal fold of gullet. *V.F.G.* = Ventral fold of gullet. × 10.

Fig. 23. Nervous system of *Patella vulgata* :—*Buc.* = Buccal commissure. *Buc.G.* = Buccal ganglion. *Cer.* = Cerebral ganglion. *Cer.C.* = Cerebral commissure. *C.-Ped.* = Cerebro-pedal connective. *C.-Pl.* = Cerebro-pleural connective. *Lab.* = Labial commissure. *L. Osph. G.* = Left osphradial ganglion. *Op.N.* = Optic nerve. *Ot.N.* = Otocyst nerve. *Ot.* = Otocyst. *Ped.* = Pedal nerve-cord. *Pl* = Pleural ganglion. *Pl.-Ped.* = Pleuro-pedal connective. *Ped.Anas.* = Pedal anastomoses. There are two such anastomoses. *R.Osph.G.* = Right osphradial ganglion. *Subœs.C.* = Sub-œsophageal connective of the visceral loop. *Supint.* — Supra-intestinal ganglion of the visceral loop. *T.N.* = Tentacular nerve. *V.* = Visceral loop. *V.G.* = Visceral ganglion. × 2.

Fig. 24. Dissection of mantle nerves in posterior region to show the anastomosis (*Z*) between the posterior pallial nerves (*P.Pal.N.*) of the two sides. The dissection is supposed to be made from the ventral surface, and a small portion of the skin is left to show the pallial tentacles (see also Fig. 8). × 8. (After a drawing by J. T. Jenkins).

Fig. 25. Longitudinal section of the cephalic tentacle. *T.N.* = Tentacular nerve. × 15.

Fig. 26*a*. Section of eye epithelium. × 800.

Fig. 26*b*. Pigment cell of eye epithelium. × 1,500.

Fig. 26*c*. Sense cell of do. *S.C.* = Sense cell. *P.C.* = Pigment cell. *P.Z.* = Pigment zone. × 1,500.

Fig. 27*a*. Section of otocyst and nerve (after de Lacaze-Duthiers). × 15.

Fig. 27*b*. Epithelium of otocyst cavity.

Fig. 28. Section of osphradium, etc. *Osph.G.* = Osphradial ganglion. *Os.E.* = Osphradial epithelium. *R.G.* = Rudimentary gill (ctenidium). × 180.

Plate IV.

Fig. 29. Heart of Patella. *N.R.V.* = Veins from the nuchal roof. *Ant.Ao.* = Anterior aorta. *L.Au.* = Auricle (morphologically left). *Post. A.* = Posterior artery. *Vn.* = Ventricle. × 3.

Fig. 30. Right kidney (after Lankester). *A.-D.Lobe* = Antero-dorsal lobe. *P.-V.Lobe* = Peri-visceral lobe. *S.-R.Lobe* = Sub-rectal lobe. *V.Lobe* = Ventral lobe. × $1\frac{1}{4}$.

Fig. 31. Diagrammatic transverse section showing the position of the renal aperture (*R.R.P.*) of the renopericardial canal of the right kidney. The anterior face of the section is drawn. × 80.

Fig. 32*a*. Diagram illustrating the structure of the kidney. *K.C.* = Kidney cavity. × 300.

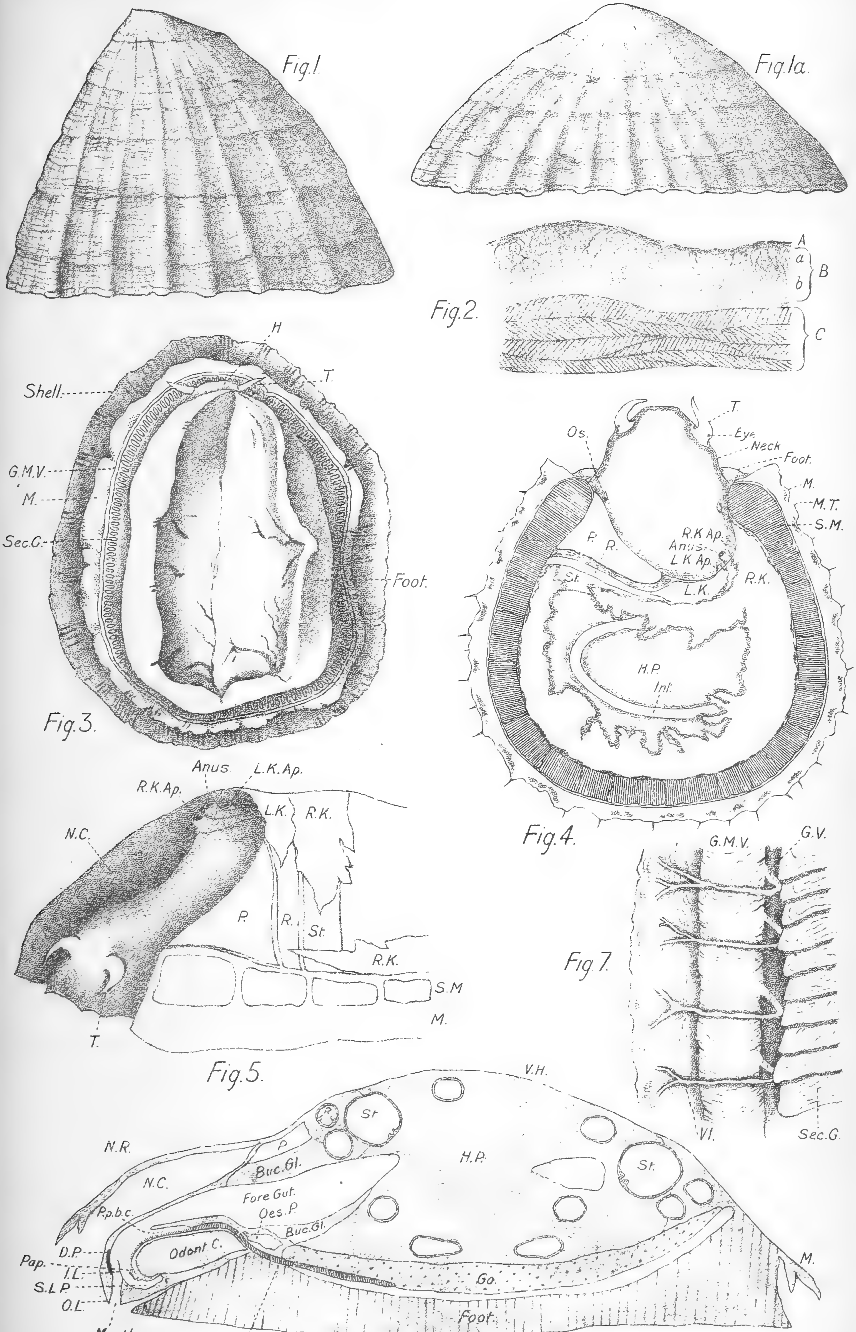
Fig. 32*b*. Epithelium of kidney. × 1,500.

Fig. 33*a*. A fragment of the ovary in section. × 300.

Fig. 33*b*. Section of young ovum. × 600.

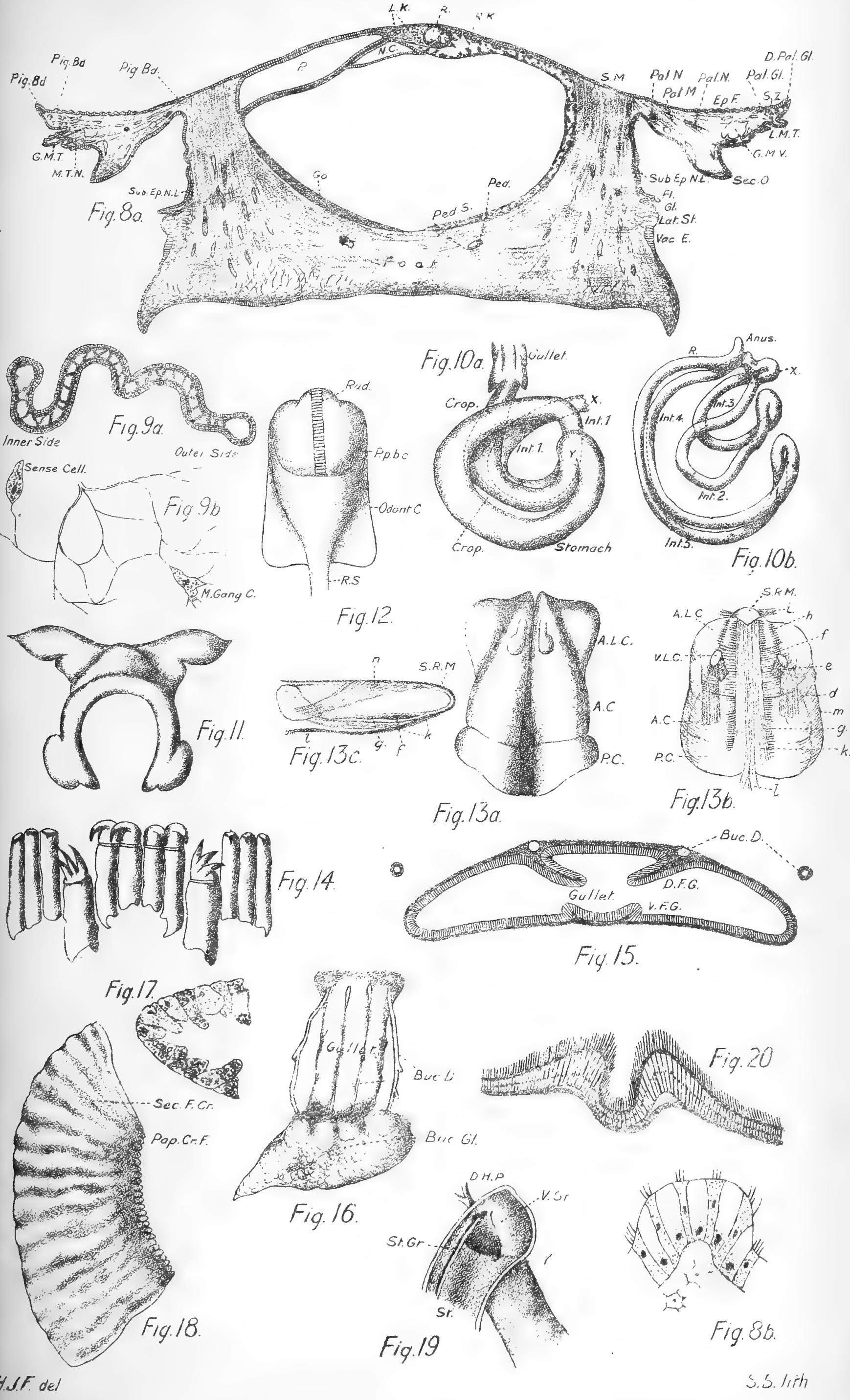
Fig. 34*a*, *b*, *c*. Diagrams showing the development of sperms in the testis (after Gibson). × *ca*. 350.

Figs. 35—42. Figures of the development of Patella (after Patten). Enlarged to various degrees. Fig. 36 is a ventral view. Figs. 37—40 are sections. Figs. 41 and 42 are views of the oral (ventral) side of the embryo. *An.C.* = Anal cells. *Ap.D.* = Apical disc. *Bp.* = Blastopore. *Cil.R.* = Pre-blastoporal ring becoming the prototroch. *Ect.* = Ectoderm. *E.-M.* = Endo-mesoderm. *Mcp.* = Micropyle. *Meso*, or *F.-R.* = Foot rudiments (mesoblastic). *Mesen.* = Mesenteron (endodermic). *Pr.-Tr.* = Prototroch. *Rect.* = Rectal evagination of midgut. *Rad.* = Invagination to form the radular sac.



H.J.F. del. S.B. lith.

PATELLA.



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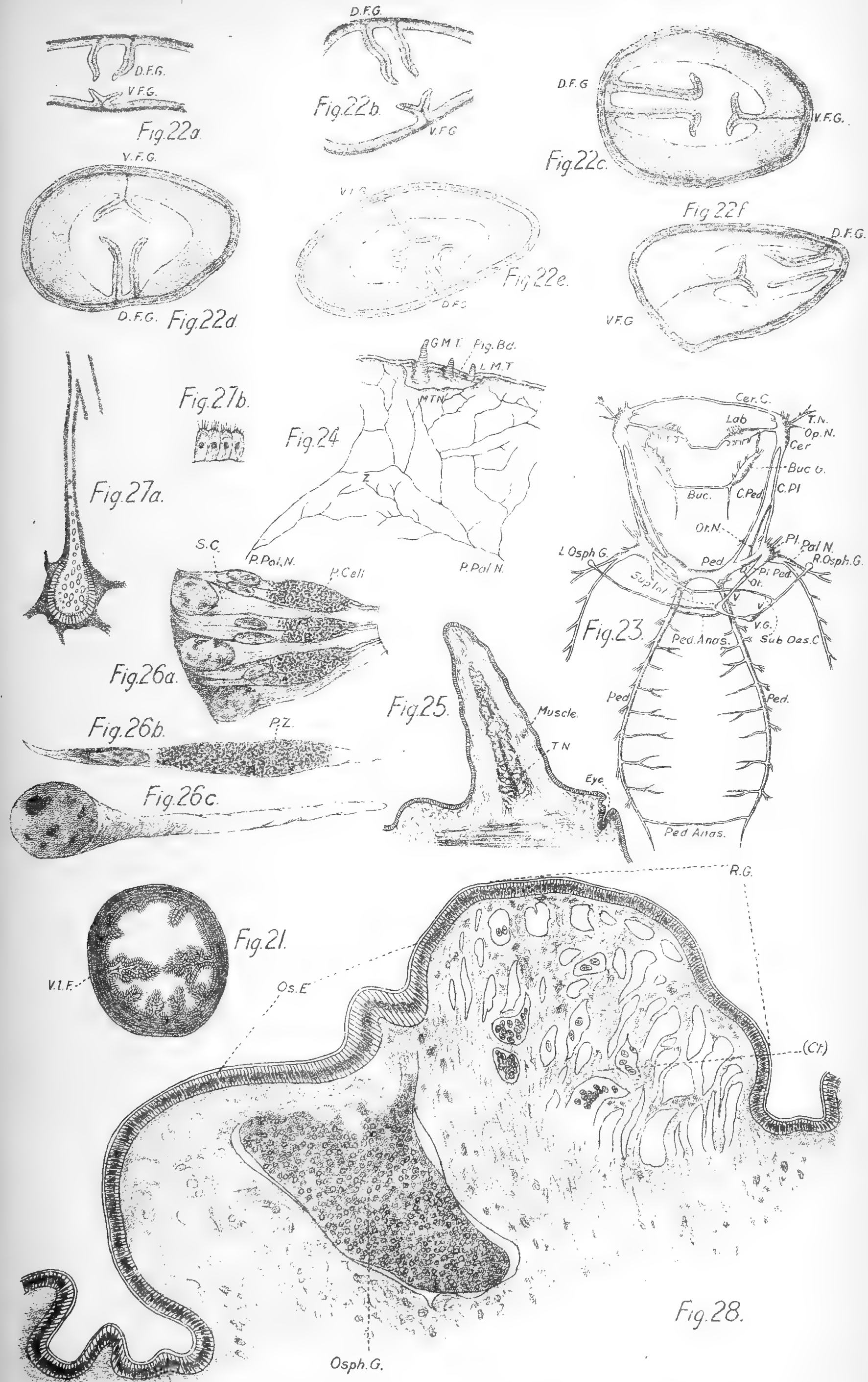
PATELLA.



H.J.F. del.   S.B. lith.

PATELLA.

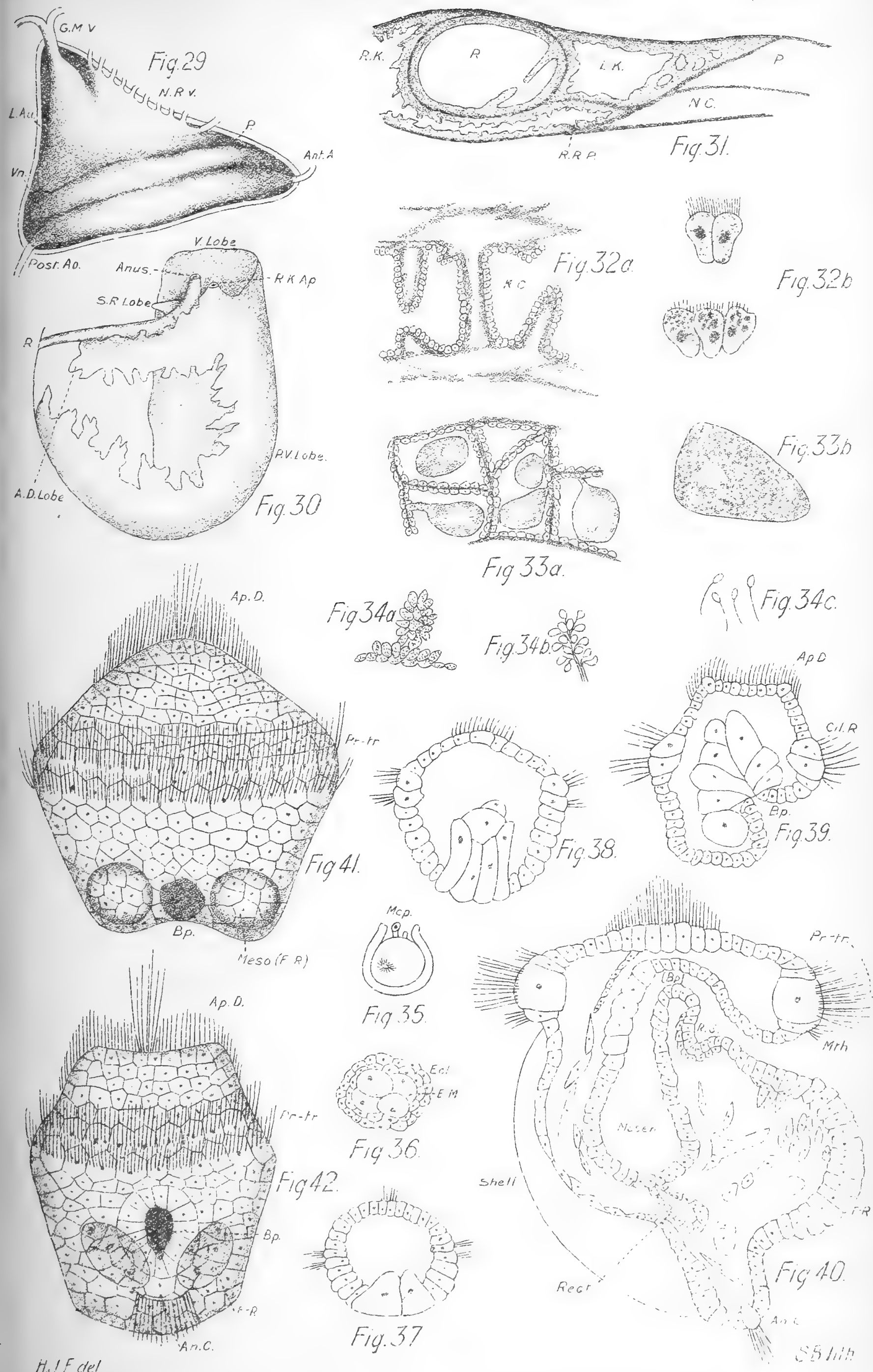


Fig. 29
G.M.V.
N.R.V.
L.Au.
P.
Vn.
Ant.A.
Posr. Ao.
Fig. 30
V. Lobe
Anus.
R.K.Ap.
S.R. Lobe
R
R.V. Lobe.
A.D. Lobe
Fig. 31.
R.K.
R
L.K.
P
N.C.
R.R.P.
Fig. 32a.
K.C.
Fig. 32b
Fig. 33a.
Fig. 33b
Fig. 34a.
Fig. 34b.
Fig. 34c.
Ap. D.
Pr-tr.
Fig. 41.
Bp.
Meso (F.R.)
Ap. D.
Pr-tr.
Fig. 42.
Bp.
F.R.
An.C.
Fig. 38.
Ap.D.
Cil.R.
Bp.
Fig. 39.
Mcp.
Fig. 35.
Ect
E.M.
Fig. 36.
Fig. 37
Pr-tr.
Bp.
Mrh
Shell
F.R.
Fig. 40.
Rect
H.J.F. del
S.B. lith

PATELLA.

NOTES ON THE CLASSIFICATION AND GEOGRAPHICAL DISTRIBUTION OF THE CEPHALOCHORDA.

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[Read January 9th, 1903.]

The following notes are the first results of an examination of the collection of Lancelets made by Professor Herdman during his recent visit to Ceylon, a collection which he was kind enough to place in my hands for examination and description. The detailed results of that examination will appear in Professor Herdman's Report on the expedition, and it will suffice now if I mention that the collection was a very rich and extensive one, consisting of 100 specimens belonging to no fewer than seven different species. Opportunity was thus afforded to study a series of specimens of several species as yet but little known, especially *Branchiostoma belcheri,* which has hitherto been found very sparingly.

As the examination of Professor Herdman's collection proceeded certain inconsistencies became apparent in the diagnoses of the various species of the group. It is these inconsistencies that I wish to discuss now, adding in addition a few notes on the geographical distribution. The history of the speciography and classification of the Cephalochorda has been detailed several times, but I think that for the sake of clearness and completeness it will be well to repeat it once more.

Amphioxus[1] was first discovered off the coast of Cornwall in 1774, by Pallas, who, though recognising its fish-like characters, described it as a mollusc under the name *Limax lanceolatus.* Sixty years later, 1834, it was re-discovered by Costa in the Mediterranean near Naples, since so famous as *the* home of Amphioxus. Costa thought he had found a new animal and named it *Branchiostoma lubricum,* taking the generic name from the oral cirri which he mistook for gills. Two years later Yarrell[2] found it again in the Mediterranean and not knowing of Costa's work, but being acquainted with Pallas' description, he re-named it *Amphioxus lanceolatus,* retaining Pallas' specific name but changing that of the genus, since *Limax* was already used for a genus of molluscs. According to the rules of nomenclature, Costa's generic name must take precedence. Hence, although popularly known as *Amphioxus,* the correct generic name should be *Branchiostoma.* Gray recognised this in 1847[3] when he described a new species from Borneo as *Branchiostoma belcheri.* His description of this new species is most vague and unsatisfactory; the reasons for separating it from *B. lanceolatum* are not at all clear, and, in fact, the author does not seem to be at all certain that it is a new species. In 1851[4] Gray compared this new species with specimens from Cornwall and the Mediterranean and concluded that all three were distinct species. The Mediterranean form he called *B. lubricum,* that from Cornwall *B. lanceolatum,* and his new one from Borneo *B. belcheri.* In 1852 Sundevall[5] added a new species from Peru under the name *B. elongatum* and at

[1] I use "Amphioxus" as a colloquial term for all members of the group.

[2] "British Fishes." 1836. [3] P.Z.S. 1847.

[4] Cat. Brit. Mus. Fish. Vol. vii. 1851.

[5] Ofvers. Vet. Akad. Förhn. Vol. ix. 1852.

the same time recorded *B. lanceolatum* from the German Ocean; and in the next year[1] he introduced the system of enumeration of the myotomes as a means of distinguishing the species of the group, and on this new character he diagnosed the 4 species already known, as follows, using three numbers to indicate (1) the myotomes in front of the atriopore, (2) those between atriopore and anus, and (3) those behind the anus:—

B. lanceolatum, with the myo. form., 36, 14, 11.

B. elongatum, with the myo. form., 49, 18, 12.

B. belcheri (formula not then known).

B. caribbœum (a new form he describes from Rio Janeiro), 37, 14, 9.

The difference between the myotome formulæ of *B. lanceolatum* and *B. caribbœum* appears very slight indeed from Sundevall's figures, and it leads us to think that he either regarded the formula as perfectly constant or that he had few specimens to work with, as the examination of a large number of specimens of each species would have convinced him of the great variation that exists within the limits of a single species. These forms were not at once regarded as specifically distinct, for Günther in 1870[2] classed them all as *B. lanceolatum.*

In 1876 Peters[3] formed a new genus for specimens from Torres Strait, Australia, which he called *Epigonichthys cultellus*, basing his genus on (1) the supposed median position of the vent, and (2) the shape of the fins. The fins, however, are such delicate structures, and, moreover, vary so within the limits of a single species that their value in determining genera is very slight indeed. Only in the best preserved material would they retain their

[1] Ibid. Vol. x. 1853.

[2] Cat. Fish. Brit. Mus. 1870. Vol. vii.

[3] Monat. K. Preuss. Akad. 1876.

exact outline, and to make their shape a generic character appears to be most unsatisfactory. Günther, in 1884,[1] re-examined this species and found that the vent was not median, but, as in all other then known species, was distinctly on the left side; he therefore very rightly referred the species back to the genus *Branchiostoma.* Although, as we shall see later, Peters' form was a type of a new genus, which has since been recognised, it was certainly not distinct generically on Peters' characters stated above. In the same paper Günther summarises the species of Branchiostomidæ and adopts Sundevall's method of enumerating the myotomes in the determination of species. Thus he now recognises as five distinct species what he, in 1870, regarded as forming one. He also added a new species, *B. bassanum,* for a Lancelet from Bass Strait, Australia. His six species (1884) are

B. elongatum	49, 18, 12
B. bassanum	44, 13, 18
	43, 15, 17
	45, 14, 17
B. belcheri	37, 14, 13
B. caribbæum	37, 14, 9
B. lanceolatum	34, 13, 13
	35, 12, 12
	36, 14, 11
B. cultellum	32, 10, 10

This summary was, however, not quite complete, as it did not include *B. californiense,* a species formed by J. G. Cooper in 1868,[2] for a form found in San Diego Bay, California. Finally, Günther[3] added a new species in

[1] Report. Zool. Collect. H.M.S. "Alert." 1884.

[2] Nat. Wealth Califor., Cronise. 1868.

[3] Challenger Reports. Vol. xxxi. 1889.

1889, *B. pelagicum*, for a surface form taken in mid-ocean during the "Challenger" expedition.

This brings us to 1893 when Andrews[1] described a new genus from the Bahamas which he called *Asymmetron lucayanum*. His minute and masterly investigation of this form disclosed two new and important characters, viz., a single row of gonads and the asymmetrical character of the metapleural folds, the left stopping at the anus, while the right was continuous behind with the ventral median fin.

These characters are at the same time very constant and very easily made out. Moreover, Andrews founded his new genus on them alone. The other points in which it differed from known forms, he regarded as merely specific differences. His new genus was, therefore, soundly based on important and constant characters. Willey,[2] in the same year, during an examination of a collection of *B. cultellum* from Torres Straits, Australia, noticed in this species the uniserial gonads, but did not agree with Andrews in regarding them as forming a generic distinction, and so retained the species in the old genus *Branchiostoma*. He apparently did not notice the asymmetrical metapleural folds, or, in all probability, he would have regarded the form as generically distinct. In 1894 Miss Kirkaldy revised the whole of the group, and her preliminary report was read to the British Association in that year,[3] the final paper appearing next year 1895.[4] Her classification was as follows:—

[1] Stud. Biol. Lab. Johns Hopk. Univ. Vol. v., pt. 4. 1893.

[2] Quart. J. Micr. Sci. Vol. xxxv.

[3] Brit. Assoc. Report. Oxford. 1894.

[4] Quart. J. Micr. Sci. Vol. xxxvii.

BRANCHIOSTOMIDÆ.

GENUS I. *Branchiostoma.*

SUB-GENUS I. *Amphioxus.*

A. lanceolatus.

A. belcheri.

A. californiense.

A. caribbæus.

SUB-GENUS II. *Heteropleuron.*

H. cultellum.

H. bassanum.

H. cingalense.

GENUS II. *Asymmetron.*

A. lucayanum.

INCERTÆ SEDIS. *B. elongatum.*

B. pelagicum.

She examined the species as to the state of their gonads and metapleura, and agreed with Willey in retaining such forms as *H. cultellum* and *H. bassanum* (both of which have uniserial gonads and asymmetrical metapleura, important, and according to Andrews, diagnostic characters of the genus *Asymmetron*) in the genus *Branchiostoma,* creating a new sub-genus *Heteropleuron* for their reception as Willey had suggested. The two forms *B. elongatum* and *B. pelagicum* she did not examine, and regarded their position as doubtful, till further specimens were examined. She also described a new species from Ceylon, *H. cingalense,* with a myotome formula of 39, 16, 8.

In the same year Gill[1] published a classification of the Cephalochorda, arrived at quite independently of that referred to above. He offered no comment on Kirkaldy's paper which reached him just as his was going to press. His classification was as follows:—

[1] American Naturalist. Vol. xxix. 1895.

BRANCHIOSTOMIDÆ, divided into five genera—

(1) *Branchiostoma*—bilateral gonads, rayed ventral fin, low dorsal fin, and expanded caudal membrane. *B. lanceolatum*, *B. belcheri*, *B. caribbæum*, *B. californiense*, *B. elongatum*.

(2) *Paramphioxus*[1]—unilateral gonads, rayed ventral fin, low dorsal fin, expanded caudal membrane. *P. bassanum*.

(3) *Epigonichthys*— unilateral gonads, reduced ventral fin, high dorsal fin and expanded caudal membrane. *E. cultellus*.

(4) *Asymmetron*—unilateral gonads, no ventral fin, low dorsal fin and extended attenuated tail. *A. lucayanum*.

(5) *Amphioxides* (a new generic name which he proposes for *B. pelagicum*)—bilateral (?) gonads, no ventral fin (?), low dorsal fin, expanded caudal membrane, no oral cirri. *A. pelagicum*.

In 1897 Willey[2] described a new species of the genus *Asymmetron* under the name *A. caudatum* the myotome formula of which was 40 (44) 9, 11; and in 1901[3] he described a further species *Dolichorhynchus indicus* which he placed in a new sub-genus of *Branchiostoma*, founded on the fact that the preoral lobe of this new species was very well developed. At the end of his paper he added an outlined classification of the group, which differed somewhat from that of Kirkaldy. The full classification was as follows:—

BRANCHIOSTOMIDÆ—

GENUS I. *Branchiostoma*.

SUB-GENUS I. *Amphioxus, e.g., A. lanceolatus*.

SUB-GENUS II. *Dolichorhynchus, e.g., D. indicus*.

[1] *Paramphioxus* is a generic name proposed in 1893 by Haeckel for *B. bassanum*.

[2] Q.J.M.S. Vol. xxxix. [3] Ibid. Vol. xliv.

GENUS II. *Heteropleuron.*

SUB-GENUS I. *Paramphioxus, e.g., P. bassanum.*

SUB-GENUS II. *Epigonichthys, e.g., E. cultellus.*

SUB-GENUS III. *Asymmetron, e.g., A. lucayanum.*

A criticism of this, as well as the other classifications, will be given later. In the same journal Benham also described a new species of Acraniate, *Heteropleuron hectori*, from New Zealand which had been laid by in a museum for twenty years labelled *A. lanceolatus.* Its myotome formula is 53, 19 (20), 12. In the same year, 1901, Jordan and Snyder[1] made a new species *B. nakagawæ* for a Japanese lancelet. In 1902 F. Cooper described a new species of *Heteropleuron, H. maldivense*, from the Maldive and Laccadive Islands. It resembled *H. bassanum* in its myotome formula and *H. cultellum* in general shape. Its formula was 45, 16, 12. In 1902 also, a new species, *B. capense* was recorded from South Africa by Gilchrist,[2] with the formula 47, 19, 9.

Such is the history of all the known species of the group. We shall now consider the various classifications. Taking Gill's first we can dismiss it in a few words.

The differences between his different genera do not appear to me to be of equal value for while *Branchiostoma* differs from *Paramphioxus* in the character of such important and constant organs as the gonads, *Paramphioxus* differs from *Epigonichthys* only in such variable and unsatisfactory points as the shapes of the fins. Moreover, his diagnosis of the genus *Amphioxides* is neither definite nor accurate, for Günther distinctly states that *B. pelagicum* has a ventral fin but no fin rays. While *Branchiostoma* and *Amphioxides* are certainly distinct from the other three genera, they cannot be considered

[1] Proc. U.S. Nat. Museum. Vol. xxiii., No. 1233.

[2] Marine Investig. S. Africa. Vol. ii., No. 7. 1902.

as themselves generically distinct, for the only difference between the two, namely the presence of oral cirri in *Branchiostoma* and their absence in *Amphioxides*,[1] is not enough to justify a generic separation, and, therefore, I agree with Günther in retaining this species in the genus *Branchiostoma*.

Similarly the three genera of Gill, *Paramphioxus*, *Epigonichthys* and *Asymmetron*, while distinct as a group from the other two genera, can hardly be considered as generically distinct from one another. The differences between them are solely the character and shape of the fins.

If we consider Kirkaldy's classification it is at once obvious that the sub-genus *Heteropleuron* is more nearly related to the genus *Asymmetron* than to the genus *Branchiostoma* in having uniserial gonads and asymmetrical metapleura, the two chief characters of *Asymmetron*. In defining the characters of his new genus, Andrews regarded the above two characters only as being generic; the other points in which the new form differs from other then known forms he considered as only of specific value. Kirkaldy on the other hand regards these latter characters as of generic value and considers Andrew's generic characters of only sub-generic rank. Willey returns to Andrew's view and in his classification places both *Asymmetron* and *Heteropleuron* under one genus defined by the above two characters. The differences between the two he considers to be of sub-generic value. His classification, however, takes no cognisance of Kirkaldy's new species *Heteropleuron cingalense*, and he neither proposes a new sub-generic name nor indicates where he would place the species.

[1] See later for reasons suggesting that the absence of oral cirri in *B. pelagicum* is the result of pelagic life.

It seems to me to be quite superfluous to form a new sub-genus for this species, *H. cingalense*, although it does not seem to fall exactly into any of Willey's sub-genera. In choosing generic characters it is well to look for those which are at once very constant and easily made out. Among the most constant of organs in any animal are the gonads, and in the Cephalochorda they are most conspicuous when present. Their arrangement, therefore, is a good character on which to classify the group. The metapleural folds are also very constant, and these together form the two fundamental, most important and most constant characters. They show two series, (1) biserial gonads and symmetrical metapleura, *i.e.*, the metapleura of both sides ending just behind the anus, and (2) uniserial gonads and asymmetrical metapleura, *i.e.*, the left metapleuron dying away just behind the anus, while the right is continuous behind with the ventral median fin. This gives us two genera. Other characters such as the shape of the fins, and the number and arrangement of the myotomes vary so much as to be only of use in determining species, and then only when taken in conjunction with other characters. I, therefore, agree with Willey in dividing the group into two genera only. The first series above gives us the genus *Branchiostoma*, and the second series the genus *Asymmetron*.

As I propose that sub-genera should be abolished altogether, the name *Asymmetron* should be applied to the second series in preference to Willey's *Heteropleuron*, because of priority. Thus we have the group primarily divided into the two genera *Branchiostoma* and *Asymmetron*.

Willey recognised five sub-genera. Three of these, *Dolichorhynchus*, *Paramphioxus* and *Epigonichthys* have only one species each, while a fourth, *Asymmetron*, has two, one of which Willey[1] subsequently regarded as merely a variety of the other. This gives us four out of five sub-genera which are monotypic. Sub-genera at most are merely groupings of species, and when each sub-genus has but one species, their reality and convenience may well be doubted. Moreover, their use indicates a less close relation between the species than really exists. For these reasons it is advisable to do away with sub-genera in this group and to divide it simply into genera and species. The classification would then be as follows:—

ORDER CEPHALOCHORDA.

Family BRANCHIOSTOMIDÆ.

GENUS I. *Branchiostoma*.

{ *B. lanceolatum*.
B. caribbæum.
[*B. belcheri*.
B. nakagawæ.] }
B. californiense.
B. elongatum.
B. capense.
B. indicum.
B. pelagicum.

GENUS II. *Asymmetron*.

A. bassanum.
A. cingalense.
A. hectori.
A. maldivense.
A. cultellum.
[*A. lucayanum*.
A. caudatum.]

[1] In 1901 when he published his classification.

In this list *B. caribbæum*, *B. belcheri* and *B. nakagawæ* are bracketed with *B. lanceolatum* because I believe that they are not specifically distinct from *B. lanceolatum* and are at most only varieties, while *B. belcheri* and *B. nakagawæ*, which are placed in square brackets, seem to be identical. Professor Lankester in a note at the end of Kirkaldy's paper, expressed the opinion that *B. lanceolatum*, *B. caribbæum* and *B. belcheri* were not specifically distinct, and I now venture to endorse that opinion, and to bring forward evidence in its favour. In the following table I have compared the characters of these three forms, with the exception of the myotomes and their arrangement.

B. lanceolatum.	*B. belcheri.*	*B. caribbæum.*
Dorsal fin of moderate height.	Same.	Same.
Rostral fin small.	Well developed.	Small.
Caudal fin lancet shaped and well developed.	Same.	Rather poorly developed.
Ventral fin with chambers and rays.	Same.	Same.
Oral sphincter vertically over 7th myot.	Same.	Over 5th myot.
12 intrabuccal tentacles.	Same.	Same.
21-41 oral cirri according to age.	Same.	Same.
Olfactory pit present.	Same.	Same.
23-29 prs. of gonads.	Same.	Same.
Aver. lengths 4·8 c.m.	4 c.m.	5 c.m.

From this table it is apparent that the closest affinity exists between these three supposed species. The differences are trivial, especially those of the fins, which, besides varying so much in one species, are so delicate that only in the best preserved material do they retain their true shape. The differences between the three forms as shown above are not sufficient to separate them specifically. It is quite evident that they have been separated merely on the arrangement of the myotomes. The number of myotomes in *B. caribbæum* is 59 to 61; in *B. lanceolatum* 58 to 62, and in *B. belcheri* 62 to 66. It will be seen that the total number of myotomes in *B. caribbæum* is the same as that of *B. lanceolatum*, the former total falling within the limits of the latter; while the total number of myotomes in *B. belcheri* never exceeds that of *B. lanceolatum* by more than three. In *Asymmetron bassanum* the range allowed is 70 to 78, a range of 8, yet in a similar range here, 58-66, three species are distinguished—an obvious inconsistency, especially when the similarity of the other characters is considered. Nor do the arrangements of the myotomes differ so markedly as to justify a separation. The average arrangement in *B. caribbæum* is 37, 14, 9; in *B. lanceolatum* 36, 14, 12, and in *B. belcheri* 38, 17, 9. The difference between *B. lanceolatum* and *B. belcheri* may appear great, but the following table, compiled from the observations of different workers, shows how the characters of one species fade gradually into those of the others, so that it is extremely difficult to decide where to draw the line between them.

Species.	Pre-atrioporal.	Pre-anal.	Post-anal.	Total.	Authority.
B. caribbæum	35	14	9	58	Andrews.
,,	36	14	9	59	Andrews.
,,	37	14	9	60	Andrews.
,,	37	15	9	61	Kirkaldy.
,,	35	15	10	60	Andrews.
B. lanceolatum	35	15	10	60	Andrews.
,,	36	15	10	61	Lankester.
,,	35	14	11	60	Kirkaldy.
,,	35	14	12	61	Andrews.
,,	36	14	12	62	Andrews.
,,	36	14	13	63	Andrews.
,,	37	14	12	63	Andrews.
B. belcheri	37	14	13	64	Günther.
,,	37	16	10	63	Kirkaldy.
,,	37	16	11	64	Tattersall.
,,	37	17	10	64	Tattersall.
,,	37	17	9	63	Tattersall.
,,	38	17	9	64	Tattersall.

The last four formulæ are taken from Professor Herdman's Ceylon material.

The transition from one species to the other is most gradual, and no reason can be given for separating the forms at any particular point. In fact, we find that two specimens with the same formulæ are put down as different species. It may be mentioned that *B. caribbæum* often has as many as 38 pre-atrioporal myotomes, and so approaches *B. belcheri*.

B. belcheri seems to be rather more distinct than the other two, but still the transition is seen to be quite gradual.

To make the inconsistency noted above all the more evident let us now consider *A. bassanum*. The total range is from 70-78, yet, as noted above, three species have been distinguished within a similar range. The differences in myotome formulæ are very marked indeed, far more so than in any of the three above species. In fact, the difference between the extreme myotome formulæ of *A. bassanum* is more decided than that between the first and last formulæ of the last given table, as the following list shows.

A. bassanum.

Pre-atr.	Pre-anal.	Post-anal.	Total.	Authority.
44	13	18	75	Günther.
43	15	17	75	Günther.
45	14	17	76	Günther.
43	16	12	71	Kirkaldy.
44	14	17	75	Kirkaldy.
45	17	15	77	Kirkaldy.
45	16	14	75	Kirkaldy.

On the above evidence it seems best to place *B. caribbœum* and *B. belcheri* under the species *B. lanceolatum* as varieties only, for the differences cannot be regarded as of specific value. There is a danger of depending on single characters and some observers have kept too closely to the arrangement and number of the myotomes alone, have not allowed for variation in the species, and have ignored other characters entirely. Sundevall made the limits of myotome variation too narrow, and later observers have not dared to extend them, though the examination of a number of specimens of each species shows how necessary this is.

Consider now the three other species, *B. californiense*, *B. capense* and *B. elongatum*.

B. elongatum was described in 1852 by Sundevall. The description was very vague and unsatisfactory, and the only valuable characteristic given is the myotome formula, 49, 18, 12. The species was found off Peru, and has not been re-discovered, and the type specimens have been lost. The true position and characters cannot, therefore, be determined till new specimens are described. Dr. D. S. Jordan suggests that this species is identical with *B. californiense*, and indeed the two species are difficult to separate, for Dr. Eigenmann, who found a shoal of lancelets in San Diego Bay, California, in 1891, suggested that they were *B. elongatum*, while Kirkaldy states they were probably *B. californiense*. It is not improbable that the two species are identical, for the extension of *B. elongatum* along the coast from Peru to California is not unlikely. It is stated that oral cirri are absent in *B. elongatum*. This is unlikely, and their apparent absence is probably due to the shrinking and bad preservation of the material. Moreover, their myotome formulæ do not differ markedly, and in view of the great variation of this character, it is probable that they are only extreme variations of the one species. *B. elongatum* has a formula of 49, 18, 12, while *B. californiense* has 45, 17, 9.

B. capense, a new species formed by Gilchrist for a South African form, is still more closely related to the Californian one. The only differences between them are (1) the presence of an eye spot in *B. californiense* and its absence in *B. capense*, and (2) the myotome formula. Gilchrist admits that his specimens were much damaged, and this may account for the absence of the eye spot, for it is very improbable that that structure is really absent. The damaged state of the specimens also prevented him from studying the variations in the myotome formula, and it is probable that, had he done so, he would have found that the myotome formula of *B. capense* overlapped that of *B.californiense*. The difference noted between *B.*

capense and *B. californiense* is very slight, and a comparison of the myotome formulæ of the three species is instructive.

B. elongatum—

Total 79. *Formula* 49, 18, 12. *Length* 39-60 mm.

B. capense—

Total 75. *Formula* 47, 19, 9. *Length* 39-48 mm.

B. californiense

Total 69-73. *Formula* {44, 16, 9 / 45, 17, 9 / 44, 19, 8} *Length* 74 mm.

It will be seen from this that they are very closely related. They agree in all other respects, and while the formulæ of *B. californiense* approach those of *B. elongatum*, the last formula given agrees very closely with that of *B. capense.*

We may reasonably doubt the separate specific identity of these three forms. Only the examination of a large collection of each will really settle the point. All three are little known forms, and in the end will probably be found to be varieties of one species. *B. indicum* agrees with *B. californiense* in all but two characters, (1) the arrangement of the myotomes, and (2) the characters of the pre-oral lobes. The total number of myotomes in each is the same, 69-73, but the arrangement differs, as the following table shows.

B. indicum—

41, 14, 14	=	69	Tattersall.
42, 14, 15	=	71	Willey.
43, 14, 13	=	70	Tattersall.

B californiense—

44, 16, 9	=	69	Cooper (J. G.).
45, 17, 9	=	71	Kirkaldy.
44, 19, 8	=	71	Kirkaldy.

The rostral fin (pre-oral lobe) of *B. californiense* is small, while that of *B. indicum* is well developed and prolonged to a length of 2 mm. in a specimen of 25 mm. total length. This difference together with the difference in the arrangement of the myotomes certainly justifies the creation of a new species but most decidedly not of a new sub-genus.

Kirkaldy expressed doubt as to the exact position of *B. pelagicum*. I think there is no doubt as to its being a species of *Branchiostoma*. Günther distinctly states that it has a double row of gonads, and it is highly probable that its metapleural folds are symmetrical; in which case it is certainly a species of *Branchiostoma*. The absence of oral cirri is, no doubt, a result of its pelagic life. The sedentary animal would require the cirri to cause currents of water to pass through the mouth, but the pelagic animal, in virtue of its motion through the water, would set up such a current without the aid of oral cirri. Their absence in this species, therefore, is not remarkable. The enlarged eye spot is another result of pelagic existence.

We shall now consider *B. nakagawæ*, the new Japanese lancelet. Andrews[1] records this species as *Branchiostoma sp.*, suggesting that it showed great affinity with *B. belcheri*, and placing it provisionally in that species.

Little was then known about *B. belcheri* as few specimens had been examined. The descriptions were very vague and Andrews hesitates to decide the point, but says that " the geographical distribution of this species favours this conclusion (that the species is *B. belcheri*) since we may easily suppose it extended from Borneo (where *B. belcheri* was first found) to Japan, as it is already known south to the Prince of Wales Island and is thus of wide distribu-

[1] Zool. Anzeiger. 1895.

tion." In 1897[1] Willey, in describing *A. caudatum*, says, "the specific differences between species of *Amphioxus* are frequently of apparently little moment, but may be of importance when taken in conjunction with the geographical distribution," and in a foot note he adds, "on this principle the Japanese *Amphioxus*, recently described by Dr. Andrews, should at least be regarded as a marked variety of, rather than identical with, *Amphioxus belcheri*;" and he suggests the name *A. belcheri*, var. *japonicum*.

In 1897 Nakagawa[2] published most detailed notes on the variation in this lancelet, on a study of over a hundred specimens, but he hesitates to call it *B. belcheri* because he had not been able to compare the two, and so leaves it as *Amphioxus sp*.

In 1901 Jordan and Snyder,[3] in reviewing the lancelets of Japan, constitute a new species for this form. The characters given by them as distinctive of this species could, however, be applied with equal truth to *B. belcheri*. The myotome formula given has also been recorded for *B. belcheri*. The reason given for forming a new species is the geographical distribution. They go even further than Dr. Willey, for while he suggested that it was a new variety only, Jordan and Snyder consider it a new species solely on account of its geographical distribution. They say, "In view, however, of the almost entire difference in species between the shore fauna of Japan and that of Borneo, it seems to us best to regard the Japanese lancelet as a species distinct from *B. belcheri*. It needs comparison with no other." It will be seen in the first place that this statement distinctly contradicts that of Dr. Andrews, as to the similarity of the shore faunas of

[1] Q.J.M.S. Vol. xxxix. [2] Annot. Zool. Jap. Vol. i., part 4.
[3] Proc. U.S. Nat. Mus. No. 1,233. Vol. xxiii.

Japan and Borneo. But, further, it seems to me quite illogical to use the known facts of distribution of a group as characters of species. It is quite absurd to suppose that two animals in all respects exactly alike in structure and form must be distinct species solely because they occur in different parts of the world.

In the present collection of Acraniates from Ceylon there were no less than 58 specimens of *B. belcheri*, by far the largest number ever collected at one time. Having so large a collection on my hands I have thought it well to make a detailed comparison of this species and *B. nakagawæ*, and this comparison certainly supports the opinion that these two forms are specifically identical. The data of *B. nakagawæ* are taken from Dr. Nakagawa's excellent tables in his notes on this form.[1]

SIZE.—The average size of *B. nakagawæ* was found by Nakagawa to be 35·74 mm.; this is the average of 119 specimens, the longest of which was 54 mm., and the smallest 25 mm. In *B. belcheri* from Ceylon, the average length of 58 specimens was 41·72 mm., the greatest length being 56 mm. and the smallest 26 mm. Thus in size they agree very closely indeed.

TIME OF SPAWNING.—Nakagawa found that the spawning time of *B. nakagawæ* was about June and July. I found that the Ceylon species spawned about March and April, that is, rather earlier than the Japanese form. This is just what one might expect from the spawning time in the tropical seas being earlier than in more temperate ones.

ORAL CIRRI.—The total number agrees closely, 41 in *B. nakagawæ* and 36-41 in *B belcheri*.

MYOTOMES.—The total number of myotomes in *B. nakagawæ* varied between 62-66, the average being 64,

[1] Annot. Zool. Jap. Vol. i., part 4.

found in 35 out of 58 specimens. In *B. belcheri* from Ceylon the total varied between 63 and 66, the average being 64 found in 31 out of 55 specimens. The commonest myotome formula for *B. nakagawæ* was 36, 17, 11, or 37, 17, 10, the former was observed 16, and the latter 11 times out of 58 specimens. In *B. belcheri* from Ceylon I found the commonest formula to be 37 (38), 17, 9, which occurred 28 times out of the best 55 specimens.

It is, therefore, evident that the closest affinity exists between the two species, as our Ceylon collection shows. In size, in number of buccal cirri, in the range of myotomes, and in the average number of myotomes, they agree exactly. The commonest formulæ of both are very close indeed. It must be admitted, then, that *B. nakagawæ* is really the same as *B. belcheri*, which, as I have endeavoured to prove, is merely a variety of *B. lanceolatum*. I append a detailed comparison of the two in tabular form.

The species of the genus *Asymmetron* are all well marked, with the exception of *A. caudatum*. There is nothing to say about *A. cingalense*, *A. cultellum* and *A. bassanum*. They are all three well characterised species.

A. hectori has only 4-6 more myotomes than *A. bassanum*. It is only known from two specimens, and although only differing in this respect from *A. bassanum*, it is well at present to keep it distinct. Its formula is 53, 19, 12. *A. maldivense* is a new species lately found near the Maldives during Mr. Stanley Gardiner's expedition. In general shape, and in the shape of the fins, it is remarkably like *A. cultellum*. Especially is this so with the dorsal fin, which is much swollen anteriorly as in *A. cultellum*. In the number of gonads and myotomes it agrees more closely with *A. bassanum*. It has 73 myotomes arranged 45, 16, 12, which is not unlike the

B. belcheri (55 Specimens).

Total Myot.	No. of Specimens with Total.	Myotome Formula. Pre-atr.	Pre-an.	Post-an.	Frequency of Formula.
66	1	39	17	10	1
65	9	38	17	10	3
		38	18	9	2
		39	17	9	4
64	31	38	16	10	2
		37	18	9	3
		38	18	8	3
		38	17	9	19
		39	17	8	4
63	14	36	18	9	1
		37	17	9	9
		38	17	8	3
		37	16	10	1

B. nakagawæ (58 Specimens).

Total Myot.	No. of Specimens with Total.	Myotome Formula. Pre-atr.	Pre-an.	Post-an.	Frequency of Formula.
66	2	38	17	11	1
		37	18	11	1
65	12	38	16	11	1
		36	18	11	1
		37	17	11	8
		38	18	9	1
		36	17	12	1
64	35	36	17	11	16
		37	17	10	11
		36	18	10	2
		37	16	11	5
		35	18	11	1
63	8	37	16	10	1
		36	17	10	4
		35	17	11	2
		36	16	11	1
62	1	36	17	9	1

arrangement in *A. bassanum*. In view, therefore, of its resemblance to *A. cultellum* on the one hand and to *A. bassanum* on the other, it seems well to recognise *A. maldivense* as a distinct species. *A. lucayanum* is also a well marked species, but it is doubtful if *A. caudatum* is more than a variety of *A. lucayanum*. *A. caudatum* is only known from two specimens both of which are larger than the average length of *A. lucayanum* which is 19 mm. according to Kirkaldy and 16 mm. according to Andrews, while *A. caudatum* measured 20 mm. to 28 mm. F. Cooper[1] finds that the length of *A. lucayanum* from the Indian Ocean is 18-20 mm., which is about the size of *A. caudatum* as observed by Willey. The difference in size is, therefore, of no account, and this brings the two species still closer to one another.

A comparison of the formulæ of the two species shows a close affinity.

A. caudatum	40, 9, 11	= 60	Willey.
	44, 9, 11	= 64	Willey.
A. lucayanum	42, 8, 12	= 62	Andrews.
	43, 8, 12	= 63	Andrews.
	44, 8, 12	= 64	Andrews.
	44, 9, 11	= 64	Andrews.
	44, 9, 12	= 65	Andrews.
	44, 9, 13	= 66	Andrews and F. Cooper.

The second formula of *A. caudatum* agrees exactly with *A. lucayanum*, while the first may only be an individual variation.

The two species agree exactly in other characters except that the rostral and caudal fins of *A. caudatum* are more deeply constricted off than in *A. lucayanum*. I do not think that these slight differences can have weighed very much with Dr. Willey in forming this new

[1] Fauna and Geography of Maldives and Laccadives. Vol. i., Part 4.

species. It was the geographical distribution which apparently was the greatest argument for its separation from *A. lucayanum.* It was during the examination of *A. caudatum* that he made the statement quoted above in discussing *B. nakagawæ,* and he evidently then thought that the slight differences between his species and *A. lucayanum* became of great importance because these forms were found at far distant points. Dr. Willey evidently had changed his opinion later when, in 1901[1], he states, "if we regard *A. caudatum* to be merely of sub-specific rank, as would seem to be the case." Moreover, Mr. J. S. Gardiner has since found *A. lucayanum* round the Maldive Islands in the Indian Ocean, and this at once does away with Dr. Willey's seeming difficulty in realising that the same species may occur in widely separated parts of the globe. The amended classification would, therefore, in view of the above discussion, be as follows:—

Order CEPHALOCHORDA, Lankester, 1877.

Family BRANCHIOSTOMIDÆ.

GENUS I. BRANCHIOSTOMA, Costa, 1834.

(*Amphioxus*, Yarrell, 1836).

B. lanceolatum (Pallas, 1774).

B. lanceolatum, var. *belcheri.*

B. lanceolatum, var. *caribbæum.*

B. elongatum, Sundevall, 1853.

B. californiense, J. G. Cooper, 1868.

B. pelagicum, Günther, 1889.

B. indicum (Willey, 1901).

B. capense, Gilchrist, 1902.

[1] Q.J.M.S. Vol. xli.

GENUS II. ASYMMETRON, Andrews, 1893.

(*Heteropleuron*, Kirkaldy, 1895).

(*do.* Willey, 1901).

A. cultellum (Peters, 1876).

A. bassanum (Günther, 1884).

A. lucayanum, Andrews, 1893.

A. lucayanum, var. *caudatum*.

A. cingalense (Kirkaldy, 1895).

A. hectori (Benham, 1901).

A. maldivense (F. Cooper, 1902).

As to which is the older phylogenetically of the two genera, I think there is little doubt that *Branchiostoma* is the more archaic, as Willey suggests. For his reason for this statement see his paper on *A. cultellum* in the Quarterly Journal of Microscopical Science, Vol. 35.

GEOGRAPHICAL DISTRIBUTION.

General Remarks.—The species of the Cephalochorda are widely distributed over the seas of the Globe, as the following tables show.

TABLE I.—Showing Distribution according to Latitude.

North Latitude.						Species.	South Latitude.					
50° to 60°	40° to 50°	30° to 40°	20° to 30°	10° to 20°	0° to 10°		0° to 10°	10° to 20°	20° to 30°	30° to 40°	40° to 50°	50° to 60°
+	+	+			+	*B. lanceolatum*						
					+	*B. belcheri*						
		+	+	+		*B. caribbæum*		+	+	+		
		+				*B. nakagawæ*						
			+	+		*B. pelagicum*			+			
						B. elongatum			+			
			+			*B. californiense*						
						B. capense				+		
				+	+	*B. indicum*						
						A. bassanum				+		
						A. hectori					+	
				+	+	*A. maldivense*						
					+	*A. cultellum*		+				
				+	+	*A. lucayanum*						
					+	*A. cingalense*						
						A. caudatum	+					

It will be noticed from Table I. that no species occur further north than 60 deg. N., and none further south than 50 deg. S. The most northerly point reached is the coast of Norway where Sundevall found *B. lanceolatum*, while *A. hectori* reaches furthest south, being found off New Zealand.

The majority of the species are found within the belt of water between 40 deg. N. and 40 deg. S. of the equator, so that the group is essentially tropical and sub-tropical, with an occasional temperate extension (see Table I.), and it is much more abundant in the Northern than in the Southern Hemisphere. The genus *Branchiostoma* is much more abundant than *Asymmetron*, and is almost exclusively found in the Northern Hemisphere while *Asymmetron* is about equally distributed in both Hemispheres. *Asymmetron* is much more tropical than *Branchiostoma*, for while the former is only found in one place outside tropical seas (*A. hectori*), the latter is decidedly temperate and one species, *B. lanceolatum*, approaches the Arctic circle.

Table II. shows the distribution of the species in the great seas of the world. It is noticeable that there is scarcely a large tract of shallow water in the whole world that does not possess at least one species of the group, and we are led to believe that far from having a discontinuous distribution as was formerly supposed, it has a very continuous and wide-spread distribution, as the latest expeditions show. While the Atlantic Ocean possesses but three species of the group, the Pacific Ocean, including the Indian Ocean and the seas of Melanesia, have no fewer than fifteen species, the Indian Ocean alone being the home of eight species. *Asymmetron* is confined, with the exception of one species (*A. lucayanum* found in the Caribean Sea, but

Table II.—Showing Distribution in the Great Waters of the World.

Species.	Indian Ocean Proper.	North Pacific.	South Pacific.	East Indian Seas.	Seas round Australia and New Zeal.	South Ocean.	North Atlantic	North Sea Mediter.	South Atlantic.	Caribean Sea.
B. lanceolatum	+						+	+		+
B. belcheri	+			+	+					
B. caribbæum							+		+	+
B. nakagawæ		+								
B. pelagicum	+	+				+				
B. elongatum			+							
B. californiense		+								
B. capense						+				
B. indicum	+									
A. bassanum					+					
A. hectori					+					
A. maldivense	+									
A. cultellum	+				+					
A. lucayanum	+									+
A. caudatum				+						
A. cingalense	+									

also in the Pacific), to the Indo-Pacific area, while the genus *Branchiostoma* is equally well distributed in both regions. It will be noticed from Table II. how extremely localised the species of *Asymmetron* are, each being found in one, or, at most, two places.

B. lanceolatum is perhaps the most widely distributed of all species. It is confined to the Northern Hemisphere and though essentially temperate it is found in tropical seas as well. It has been recorded from the English Channel, North Sea, Coast of Norway, Firth of Clyde, the Mediterranean, especially at Messina and Naples, all along the Atlantic shores of North America from Chesapeake Bay to Florida, and from Ceylon (Herdman). With the single exception of Ceylon it is confined to the Atlantic Ocean.

B. belcheri is a purely tropical and Indo-Pacific form. It has been recorded from Borneo, Singapore, Torres

Straits, Maldive Islands (J. S. Gardiner), and Ceylon (Herdman).

B. caribbæum is only known from the American side of the Atlantic Ocean. It is a sub-tropical form and has the widest range of latitude of all species (see Table I.), extending from 40 deg. N. to 40 deg. S. of the Equator. It has been recorded from St. Thomas' Islands; Kingston, Jamaica; Gulf of Mexico; Birdshoal, North Carolina; Rio de Janeiro; mouth of the Plate River; Bay of Botafago, and Port Tampa.

B. nakagawæ is known only from Japan. If, as I have endeavoured to show, these four species are really one or at most only varieties of one single species, then the distribution of *B. lanceolatum* becomes world-wide, and it is an example of a truly cosmopolitan form.

B. californiense has only been recorded from San Diego Bay, California.

B. elongatum has only been once taken, and that as far back as 1852, from the coast of Peru.

B. capense is known only from the South and Eastern waters of South Africa.

B. pelagicum till quite recently was only known from the Sandwich Islands where a single specimen was captured by the "Challenger." From Mr. F. Cooper's paper on Cephalochorda of the Maldives, we learn that Mr. J. Lister, as far back as 1888, caught a specimen of *Branchiostoma* in the South Indian Ocean, which has been identified as *B. pelagicum* by Mr. Cooper. Later, Professor Herdman's expedition demonstrated the existence of this species in the Indian Ocean near Ceylon and the Maldive Islands.

B. indicum is quite locally distributed, being found only in the Bay of Bengal, near the Orissa Coast, and at Ceylon (Herdman).

Asymmetron bassanum is found only in the Bass Straits, Australia, and round the coast from there as far north as Port Jackson.

A. hectori is known only from the East coast of the North Island of New Zealand.

A. cultellum has been recorded from Torres Straits, North-east Coasts of Australia, Thursday Island, and at Ceylon (Herdman).

A. maldivense occurs near the Maldives, and at Zanzibar.

A. cingalense is known only from Ceylon.

A. lucayanum has the widest distribution of all the species of *Asymmetron*, being both an Atlantic and an Indo-Pacific form. It was first recorded from the Bahamas, where Andrews, its discoverer, found it in 1893. Then in 1897 Willey found what he thought was a new species of this genus, *A. caudatum*, in the Louisiade Archipelago and Lifu. As *A. caudatum* is more likely to be only a variety of *A. lucayanum* we are justified in extending the distribution of this form to the East Indies. Mr. J. S. Gardiner has still more recently found *A. lucayanum* round the Maldive Islands, while Mr. Crossland also finds it at Zanzibar. We can quite agree with Dr. Willey when, in describing *A. caudatum*, he makes the following statement, "that it (*A. caudatum*) should be entirely distinct from its relations in the Torres Straits, from whom it is removed by a distance of less than 600 miles, and on the other hand closely allied to a species residing in the Bahamas upwards of 8000 miles away on the other side of the American continent, is certainly a noteworthy fact of distribution." Later in his Zoological Results[1], speaking of the same species, he says, "I was not a little surprised to find a representative of this West

[1] Zool. Results. Part 6. 1902.

Indian species in the Louisiade Archipelago and subsequently in Sandal Bay, Lifu, although it is a fact that there is a strong Caribæan element in the fauna of the Indo-Pacific." This last remark has received further support in the finding of *A. lucayanum* (the identical species of Andrews, and known only previously from the Bahamas) in the seas round the Maldives, and this is one more link in the chain of evidence in support of the current theory that there was in former times a continuous connection between the Pacific and Atlantic Oceans.

Finally, species of Cephalochorda are found in the littoral waters of all the great continents, and we may feel sure that the more fully these littoral waters are worked, especially of the seas round Africa, about which we at present know so little[1], the more widely and generally distributed will we find *Amphioxus* to be.

I must express my thanks to Professor Herdman for his great kindness and help in the preparation of this paper, and also for valuable aid in dealing with the literature of the subject.

I append a table for the identification of the species of the Group.

CEPHALOCHORDA, Lankester, 1877.

Family BRANCHIOSTOMIDÆ, divided into two Genera:—

Genera:—

GENUS I. *Branchiostoma*—Metapleural folds end symmetrically just behind the anus, separated by the ventral fin; gonads disposed in two lateral series, ventral fin

[1] In support of this assertion I notice that in Mr. F. Cooper's paper on the *Cephalochorda* of the Maldives (which has appeared while the present paper was going through the press) it is stated that Mr. Crossland has found two species, *A. maldivense* and *A. lucayanum*, off Zanzibar, a region hitherto unworked.

with fin chambers which may or may not have fin rays, oral cirri when present have sense papillæ, atrial chamber prolonged behind the atriopore in a single right cœcum.

(*A*) *Species having oral cirri.*

(*i.*) *in which pre-oral lobe is normal.*

(*a*) *Myotomes* 58-66.

B. lanceolatum—average length 48 mm.; myotomes 58-62; average formula 36, 14, 12; rostral fin small; 12 intra-buccal tentacles; ventral fin with fin rays; 21-41 oral cirri; 23-29 pairs of gonads; oral sphincter vertically above 7th myotome.

B. belcheri—Average length 45 mm.; myot. 62-66; average formula 38, 17, 9; rostral fin large. Other characters as in *B. lanceolatum.*

B. caribbæum—Average length 40 mm.; myot. 59-61; average formula 37, 15, 8; oral sphincter over 5th myotome. Other characters as in *B. lanceolatum.*

B. nakagawæ—Average length 35 mm.; myot. 62-66; average formula 37, 17, 10, or 37, 16, 11; Other characters as in *B. lanceolatum.*

(*b*) *Myotomes* 69-79.

B. californiense—Average length 74 mm.; myotomes 69-73; average formula 45, 17, 9; rostral fin small; oral cirri small; 31 pairs of gonads; oral sphincter over 4th myotome; ventral fin with fin rays.

B. capense—Length 39-48 mm.; myot. 75; formula 47, 19, 9; 36 oral cirri; no eyespot (?); 30 gonads; rostral fin and oral cirri normal.

(*ii.*) *Species with a well developed pre-oral lobe, into which the notochord is prolonged.*

(*a*) *Myotomes* 71-73.

B. indicum—Length 25 mm.; myot. 71-73; formula 42, 14, 15; pre-oral lobe 2 mm. long on an average. Other characters as in *B. lanceolatum.*

(*B*) *Species in which oral cirri are apparently absent.*

B. pelagicum—Length 10-21 mm.; myot. 65-67; formula 36, 16, 15; 26 pairs of gonads; ventral fin with no fin rays; eyespot very prominent.

B. elongatum—Length 60 mm.; myot. 79; formula 49, 18, 12.

GENUS II. *Asymmetron*—Left metapleuron stops just behind the anus, the right is continuous with the median ventral fin; gonads disposed in a single right series; oral cirri with or without sense papillæ; intra-buccal tentacles 10-16; ventral fin with or without ventral fin chambers or rays; post-atrioporal cœca 1-2 in number.

(*A*) *Species in which a urostyloid process is absent;* oral cirri are present and bear sense papillæ; ventral fin is divided up into fin chambers; single post-atrioporal cœcum.

(*i.*) *Ventral fin possesses both chambers and rays.*

A. bassanum—Length 43 mm.; myot. 70-78; formula 45, 16, 14; rostral fin well developed; 31-33 oral cirri; oral sphincter over 7th myot.; 16 intra-buccal tentacles; 26-31 gonads; ventral fin rays single.[1]

A. hectori—Length 53 mm.; myot. 84; formula 53, 19, 12; ventral fin rays and chambers prolonged postanally. Other characters as in *A. bassanum.*

A. maldivense—Length 22 mm.; myot. 73; formula 45, 16, 12; dorsal fin swollen anteriorly; gonads 26; ventral fin rays single; oral cirri 23. Other characters as in *A. bassanum.*

A. cingalense—Length 27 mm.; myot. 61-64; average formula 39, 16, 8; gonads 20-26; ventral fin rays double; oral cirri 26-32;

[1] There seems considerable doubt as to whether the fin rays are paired or single. Miss Kirkaldy (*loc. cit.*) states that they are paired. Dr. Benham (*loc. cit.*), on the other hand, asserts they are single.

other characters as in *A. bassanum.*

(*ii.*) *Ventral fin has fin chambers but no fin rays.*

A. cultellum—Length 35 mm.; myot. 50-56; formula 32, 10, 10; dorsal fin swollen anteriorly; notochord club-shaped at anterior end; oral sphincter over 6th myotome; 41-43 oral cirri.

(*B*) *Species with a long urostyloid process* into which the notochord is prolonged; oral cirri have no sense papillæ; post-atrioporal cœcum paired; ventral fin with neither fin rays or fin chambers.

A. lucayanum—Length 16-30 mm.; myot. 63-66; average formula 44, 9, 13; oral sphincter over myot. 8; 10 intra-buccal tentacles; 21-29 pre-oral cirri; 26-29 gonads; no nephridia according to F. Cooper.

A. caudatum—Length 20 mm.; myot. 60-64; formula 44, 9, 11; rostral fin and caudal process separated from the rest of the body by a constriction. Other characters as in *A. lucayanum.*

OBSERVATIONS ON THE HABITS OF THE ONUPHIDÆ (POLYCHÆTA), AND ON THE INTERNAL STRUCTURES WITH WHICH THEY FORTIFY THEIR HOMES.

By Arnold T. Watson, F.L.S.

(With a Plate).

(Read 20th February, 1903.)

The Onuphidæ are marine bristle-footed worms, varying in the British species from, say, one to four inches in length, some of the foreign species being much larger.

They are somewhat centipede-like Annelids. The body consists of a considerable number of segments, the first of which is a well-defined head, with conspicuous eyes, and several tentacles directed more or less forward. The second segment contains the mouth, with its swollen palps and complicated, savage-looking jaws; then follow a great number of segments, each swelling out on either side, to form the parapodium, a lobe through which pass and protrude laterally bristles of various kinds, which need not now be particularised, beyond saying that some are much stronger than others, and forceps-like at their outer extremity. The first pair of parapodia (for reasons which will appear later) have a forward direction; the succeeding feet stand out laterally, more or less at a right angle to the body. All are capable of a muscular rowing movement, like the oars in a boat. The body is reddish-yellow, and iridescent, and diminishes in size towards the posterior extremity, which terminates with a pair of thread-like cirri. There are in addition branchiæ of characteristic form, cirri, and various other appendages, which, for my present purpose, it is needless to specify. These worms live, on the sea-bottom, in tubes, to be hereafter more fully described, which they form for their own protection.

The Onuphidæ are very closely allied to a much commoner and better known family, the Eunicidæ, but, as McIntosh has pointed out, they differ from them (amongst other things) by one very evident feature, their bathymetrical distribution; for whereas the Eunicidæ are frequently found between tide-marks, the Onuphidæ are characteristic of deep-water, many of them ranging to very great depths.

Possibly their comparative inaccessibility may account for the fact that, so far as I know, actual observations on their habits have hitherto been unrecorded, though certain conjectures on the subject are made by Dr. Johnson, in his Catalogue of Worms in the British Museum. My own observations, which, as regards living specimens, have been confined to the behaviour of the two British forms, *Hyalinœcia tubicola* and *Onuphis conchilega*, in captivity, clearly show that the conjectures referred to are very wide of the mark. It will be remembered that Johnson draws the picture of *Hyalinœcia* (*Nothria*) *tubicola*, with its quill-like, tapering tube (fig. 1) standing embedded in, and subject to, the pressure of the soft mud in which it is said to live. The anterior portion of the body is supposed to be protruded beyond its tube, and to be raised above the surface of the mud, remaining in this position on watch for prey. He further conjectures that with the forceps-like bristles of the feet, the worm hooks itself to the rim of the tube, and thus obtains a support, without waste of muscular power, "a long watch," he says, "being thus rendered less irksome."

In my aquaria, these worms were by no means thus sedentary; on the contrary, when not alarmed, they were very active, and travelled about freely, carrying their tubes with them, the movement of which was effected by protruding half an inch or more of the anterior portion of the body from the front end of the tube, and by muscular effort jerking the tube, or dragging it, with a caterpillar-like action, into new positions.

The distinctly curved form of the forceps-like bristles of the first parapodia gives the worm, when travelling about, a firm foot-hold on the sea-bottom, and is doubtless connected with this habit, as is possibly also the bract on the fore feet. During movement the hold on the tube itself is doubtless retained by the stout forcipate bristles of the other parapodia.

To keep these worms alive in captivity, I found it necessary to cover the floor of the aquarium with muddy sand and shells obtained, by means of a bucket dredge, from the sea-bottom upon which the animals were captured. Under these conditions they lived for several months, subsisting upon the food obtained from the mud, their habits in this respect evidently being less carnivorous than Johnson supposed.

Only when alarmed, as for instance, when rocked about by movement of the aquarium, or by some unusual circumstance (such as my subsequent experiments), did they show any desire to embed themselves; but on such occasions *Hyalinœcia* will protrude the fore part of its body through the small end of the tube, and quickly burrow partially under the surface, dragging its tube with it.

The tube of *Hyalinœcia tubicola*, as is well known, is a transparent, chitinous, quill-like structure, from 2 to 4 inches in length, slightly curved and tapering, as shown in fig. 1, from the anterior (*a*, fig. 1) to the posterior end (*p*, fig. 1). It is open at both extremities, and usually of a pale yellow or brownish colour, prettily ornamented, more especially towards the two ends, by V-shaped, or zigzag markings of distinctive tint. These markings are indicative of a very interesting internal structure at either end of the tube, namely, the valves, or diaphragms, which have been noticed, as existing only in *Hyalinœcia*, by Ehlers and McIntosh, though their function has not, I believe, been hitherto explained.

These valves take the form of membranous pockets inside the tube attached to opposite walls, the opening of the pockets directed outwards. Their function is doubtless protective. Each end of the tube is usually guarded by two or more pairs of valves. At the wider end of the tube the valves (*v*, fig. 1) are attached at the same level, and closure is effected by their meeting in the middle, but at the narrow end they (*v′*, fig. 1) are not attached at the same level; they consequently become alternate, and, closing more or less nearly on the opposite wall of the tube, give rise to the zigzag marking.

The worm, travelling along the sea-bottom in a tube open at both ends, would (except for this provision) be always exposed in the rear to the attack of enemies.

These valves which, like the valves in a vein, close automatically by the inrush of water, on the retreat of the worm (assisted, probably, by the elasticity of the valves themselves), act as an effectual barrier against foes.

I have on many occasions been fortunate enough to see this automatic closing of the valves; in fact, it was the perfect resistance which they offered to an attempt to expel the worm that first attracted my attention.

On the occasion referred to, the attempt was being made with a small syringe applied to one end of the tube; but accidentally the water was discharged before the syringe could be got into position. Upon trying to refill the syringe by slowly drawing water through the *Hyalinœcia* tube, the effort proved ineffective, excepting when the worm, which was occupying the central portion, occasionally moved forward. A few drops of water then entered the syringe, whereupon the animal quickly retreated, and the supply instantly ceased. Patiently waiting and watching, this experience was repeated many times, and drop by drop the syringe was filled, when the worm was ejected, the protective valve at the syringe end having been broken by it. This intermittent action, of course, suggested the existence of hidden valves in the tube, and these, when sought, were easily found. They open readily in response to a forward movement of the animal, or of the water inside the tube, and are closed instantly by the inrush of the surrounding water on the worm's retreat. This action of the valves is illustrated diagrammatically by fig. 2, representing the anterior, and figs. 3 and 4, the posterior end of the tube. In figs. 2 and 3 the arrows indicate the inrush of water closing the valves; pressure in the opposite direction, of course, opens them. Fig. 4 shows the position of matters when, having reversed, the worm emerges at the smaller end, as indicated by the dotted line and arrow. It will be noticed that the valves (v', v'', v''') are opened, the membrane bulging in the opposite direction.

The tube of *Hyalinœcia* is evidently formed by a secretion of the worm, and lengthening takes place by addition at the wider end. This extremity is always much thinner, and paler in colour. As the animal grows the tube is lengthened and widened proportionately, and it seems most probable that, in opposition to Johnson's suggestion, the worm dwells in one tube all its life, the portion occupied when the worm was young and little being bitten off by its jaws, when it finds the aperture becoming inconveniently small. This view is supported by an instance of shortening of the tube actually seen in *Onuphis conchilega*, to which reference will be made later; and it is further confirmed by the fact that frequently *Hyalinœcia* tubes bear clear internal evidence of this having taken place, since, as the tube is lengthened, the old valves are removed and reconstructed in new positions, traces of the old valves often being left permanently on the walls of the tube. Specimens in my possession thus show clearly that the present site of the hinder (alternate) valves was once occupied by the front (opposite) valves made by the younger worm.

Although the tube itself is undoubtedly formed simply by secretion poured out direct from the body of the worm. the internal valves (*v*, *v'*, fig. 1) which guard it are produced in a very different manner. They are a later production, most skilfully constructed by the worm. Their thicker portions attached to the walls of the tube are probably due to the action of the jaws, palps and mouth parts, aided possibly by the fore feet of the animal, manipulating material obtained from the coating of the tube, or even from old valves, which is worked up for the purpose in the mouth of the worm; while the delicate free membranous edge of the valves may be formed by direct secretion, like the tube itself. The experiments upon which this opinion is based require further confirmation, but they are briefly as follows:—

Two healthy specimens of *Hyalinœcia*, which had become acclimatised in my aquaria, were selected, and at different times (a few days apart) the portion of each tube containing the valves at the wider end was cut off, without injury to the worm. In a short time the worms, on both occasions, realised the position, and commenced biting vigorously with their jaws at the luting of the trough in which they were placed, at the cut end of the tube, and at its outer skin, in which latter operation the animal exposed fully $1\frac{1}{2}$ inches of its body, bent U-shape by crawling over the wall and down the outside of its tube. All these proceedings differ entirely from the ordinary behaviour of the worms as observed during several months, both before and since.

The worms were carefully watched for some hours, but in neither case was a valve formed during that period, though both worms, afterwards, when in the dark, soon replaced them, and in one instance the damage was actually repaired within 12 hours after the cutting of the tube. Though I have not yet been fortunate enough to see the complete process of forming these valves, I have on several occasions during my experiments seen the worm apparently operating with its mouth upon the newly-formed membrane, on which, as well as upon the wall of the tube itself, evidence seems to be left in the shape of irregular coarse striations and cross-markings. It, therefore, appears probable that the unusual biting witnessed immediately after the cutting of the tube, and subsequently, was an effort on the part of the worm to collect material for the formation of new valves. A single pair of very perfect, opposite valves was formed in each case, which would suffice for the purpose of immediate protection. A few weeks later the tubes were slightly lengthened, and a second pair of valves constructed.

After an interval of ten weeks I experimented again with the same two worms, being unfortunately unable to get fresh specimens. On this occasion the newly-formed anterior valves were cut off the tube of one specimen, and the old posterior, or alternate valves from the other. The worms had been in captivity three months, and although apparently fairly healthy, were less vigorous than at my first experiments. Neither worm showed the excitement or activity of the first occasion. The first specimen refused to replace a second time the anterior valves and began to fail in health; but the other worm replaced the posterior pair (alternate valves) one at a time, three or four days, apparently, being occupied in the formation of each.

Returning to the structure of the tube itself, two features in the arrangement of the valves therein are at first sight surprising, (1) the perfect alignment of all the valves (both front and back), and (2) the difference in arrangement of the former and latter, and the mathematical accuracy with which the valves are shaped. An explanation of all these wonders may, perhaps, be found in the form of the tube itself, which not only tapers considerably from one end to the other, but is also more or less elliptical in cross-section. The free edges of the valve-membrane always represents the major axis of the ellipse, and it seems not improbable that the animal may itself usually assume a definite position inside the tube in relation to this axis, and thereby be guided in orientating the valves as described. The valves at both ends of the tube, it will be remembered, are constructed upon the same principle, namely, that of the valve in a vein, but the pockets at the smaller or posterior end, instead of being opposite are alternate. It seems to me that this peculiar arrangement, which is somewhat similar to that met with in the smaller veins, may be satisfactorily explained by lack of room in that part of the tube for the necessary free movement of the animal's head.

Although, so far as I am aware, this interesting defensive mechanism has not been observed in other groups, I have been fortunate in finding it in the tubes of other members of this family.

Onuphis conchilega secretes a much flatter, elliptical, transparent tube, which it protects with fragments of bivalve shells, or flat stones, &c., thus forming a scabbard-like structure, as shown in figs. 5 and 6. By carefully dissolving away this outer covering with weak acid, I have found the protective valves in this species also (*v*, fig. 7), though they are far more delicate than those of *Hyalinœcia*. The end view of the elliptical transparent tube and valves is shown by fig. 7*a*. The habits of this worm are, moreover, exceedingly interesting in other respects. Its tube is constructed of the shells, &c., amongst which the animal lives, and consequently corresponds so closely with the surrounding sea-bottom as to afford splendid protection.

In the British specimens from Liverpool Bay and Plymouth which have come into my hands, the tubes have varied in length from $1\frac{1}{2}$ to 3 inches, and in width from $\frac{1}{4}$ to $\frac{3}{4}$ inch. Their anterior and posterior ends respectively can generally be recognised, the former being terminated with a larger overhanging shell or flat stone (*a*. fig. 5), which completely hides the internal tube and its protective valves, while at the posterior end (*p*. fig. 6) a scrap of membranous tube can frequently be seen, covered with mud or very small fragments of shell, &c., closing by collapse upon the overlying shell. Each edge of the sheath is protected by a little wall of sand grains, built in between the flat sides, and keeping them apart. These are clearly seen after treating a shelly-tube with acid, and are shown at *w*, fig 7. The tube has also an upper (fig. 5) and a lower side (fig. 6), the former being the one to which the overhanging shell is attached, though there is reason to think that the honour (?) is only temporary, and that as the tube is lengthened the uppermost position is assumed by the opposite sides alternately.

Like *Hyalinœcia*, *Onuphis conchilega* travels about the sea-bottom in a caterpillar-like fashion. Should its tube be overcast (as shown by fig. 6), it speedily rights it again. On such occasions the worm protrudes from the front end of its tube $\frac{1}{2}$ to $\frac{3}{4}$ of an inch of the fore part of its body, bending it sideways over one edge of the shell which ought to be overhanging (*a*, fig. 6), and then, by a sudden muscular twist of the body, the tube is turned over into its proper position. I have witnessed this many times! Under the shelter of the overhanging front (*a*, fig. 5) the worm is safe in exploring the immediate neighbourhood in search for food, and also for material suitable for extending its dwelling. When one of these beautiful flat tubes was first placed in my hands by Professor Herdman, I was quite at a loss to imagine a method by which the worm could construct it; but with the knowledge since gained of the peculiar habits of this species, and aided by information gained by using the transparent-tubed *Hyalinœcia* as a key to those of the family generally, the difficulty has disappeared.

The post-larval stage, and very young specimens of this worm, have unfortunately hitherto escaped us, consequently my theory requires confirmation,; but, guided by analogy, it seems most probable the formation of the tube is much as follows:—A membranous tube will first be secreted by the young worm. In this it will settle down (like *Terebella* and *Pectinaria*) to the sea-bottom, upon which it will creep, like *Hyalinœcia*, until it meets with a minute, flat fragment of shell, or other material suitable for attachment to the under side of its tube. This, properly secured by secretion or action of the head parts (a point which I am still investigating), will form the first overhanging shield.

It is possible that in making the attachments small grains of sand may be affixed on either side of the membranous tube, thus forming the first side-walls, though perhaps these may be filled in a little later. (Such advanced walls exist in several of my specimens). This done, the worm will make practical use of its shelter by turning the tube over, so that the little shell shall overhang the mouth of the tube. So protected, the worm will travel along until it finds another suitable flat fragment, which in its turn is firmly attached to the membranous tube (and side walls) on the opposite side to the first, and in such a position as to extend in advance. The wall-building and tube-turning processes are then repeated, and this worm searches around for a third shell. The edge of this, when found, is brought into contact with the front edge of the first shell (now once more on the sea-bottom), and it is so cemented and affixed to the tube, which thus grows, the process being repeated to any extent, the internal lining and protective valves being also formed accordingly. Though the foregoing is to some extent an imaginary sketch, it is partially confirmed by observation of the process adopted by the worm when its tube becomes inconveniently long and heavy. In such an event a portion will be detached. A specimen from Plymouth, the tube of which was about 3 inches long, and consisted chiefly of flat pieces of stone, while in my aquarium found this too great a load to pull about, and one evening, when I was watching, separated a portion an inch long. The stones were loosened from each other by the jaws, or some other means, invisible, owing to the operation taking place inside the tube. The result was, of course, a fracture, leaving the tube terminated by a flat stone, upon which were left the two little sandy side walls; the end of the inner tube was cut, and for the moment unprotected.

After ascertaining the position of affairs, the worm turned its tube over so that the flat stone should overhang, and then proceeded to protect the mouth by secreting a short terminal portion between the walls, attaching thereto a flat shell of smaller size than usual. It thus avoided increasing the length of the tube. It will be noticed that in this instance the small shell was actually found and affixed in the way supposed in the suggested building process.

In captivity these worms appear to be less hardy than *Hyalinœcia.*

What their natural enemies may be I do not know, but while in my aquarium I lost one specimen, devoured by a small Gephyrean worm *Thalassema neptuni*, which tore away the back end of the *Onuphis* tube, entered and remained therein twenty-five days, having barricaded the front end of the tube by drawing in a large grain of sand.

I have thus far dealt only with the habits and defensive mechanism of the British species of the family, but perhaps the most interesting example of these protective valves is afforded by the tube of *Nothria pycnobranchiata*, for the privilege of dissecting and examining which I am indebted to Prof. F. Jeffrey Bell, of the British Museum (Natural History) at South Kensington.

The specimen, which had been obtained by the "Challenger" Expedition off the Chilian Coast, from a depth of 2,225 fathoms, was a fragment about $4\frac{1}{4}$ inches long, evidently one end only of a tube. It consisted of a tough membranous inner sheath, coated outside with fine mud, and strengthened on the upper side, with the tests of foraminifera and other matter. It was elliptical in section, and 7-16ths of an inch across in its widest part.

On splitting open the extremity by cutting in the direction of its shortest axis, two pairs of very perfect internal valves were exposed, the pockets being one-quarter of an inch deep, and one in advance of another, as shown, *v*, *v*, fig. 8. Probably this was the posterior end of a tube.

From the foregoing examples, it appears that this interesting method of defence obtains throughout the family. Whether it is confined to the Onuphidæ, or not, I cannot say, but personally I am not aware of any other instance. Possibly careful search might prove its existence in some species of *Eunice*, or in other unsuspected quarters.

What may be the habits of these worms inhabiting the deepest part of the ocean can only be conjectured; but judging from the formation of the foot-bristles (as figured by McIntosh in the "Challenger" Report), from the internal structure of the tube, and from the fact that one side of the tube is usually smooth, it seems probable that they, like our British forms, may be wanderers. This view cannot, however, be taken without exception, and I freely admit that the case of *Nothria willemœsii*, from Japan, with its hooked and spine-covered tube, is one which presents very great difficulties.

It is hard to suppose that this tube (a masterpiece of constructive skill) was ever dragged about the sea-bottom, powerful though its tenant evidently was. Moreover, about one-third ($1\frac{1}{4}$ inch) of the tube at one extremity is somewhat flexible, and perfectly free from the long slender spines with which the remaining two-thirds is beset (as regards two-thirds of its circumference), suggesting the possibility that this extremity may have been embedded in the muddy bottom.

By the kindness of Prof. Bell, I some years ago examined these tubes at the British Museum, and made a rough sketch (fig. 9) of the specimen above referred to.

The tube is about $\frac{1}{4}$ inch in internal and $\frac{3}{8}$ inch external diameter. It is lined with a tough whitish secretion. Some of the spines are curved, others straight and varying from 1 inch to $1\frac{1}{2}$ inches in length. They are hollow, and formed of a white porcellaneous material, probably the same as the lining of the tube. At the base they are much swollen, the hollow bulb being filled with fine sand, similar to the coating of the main tube. The porcellaneous coating is very thin, and drawn out to a fine point which is transparent, the internal tapering cavity being visible, and closed at the tip. The method by which these spines were actually formed is, of course, unknown. They are not socketed on to the main tube, but are very firmly attached to it by the parchment-like material with which the spines are coated. Numerous small pieces of this material project at intervals outside the tube. In two instances these are triangular in form, $\frac{1}{8}$ inch wide at the base, where attached to the tube, and $\frac{1}{2}$ inch long, tapering to a point.

These strips suggest, I think, a probable method of formation of the spines. It is very likely they were formed at the mouth of the tube as foundations for spines, and were afterwards abandoned. Two spines actually in this position are shown in fig. 9, one of them being in fact a continuation of the edge of the tube. Like the valves in the tube of *Hyalinœcia*, these structures are most probably formed by the mouth of the worm, the sand being also thereby collected and secured in position by the longitudinal folding of the triangular strips, which are then, by further additions of the secretion, worked up into the long spines shown upon the figure. For further information, reference should be made to the "Challenger" Report, vol. xii., pp. 325 and 326.

As regards defensive mechanism, it is well known that many species of tubicolous worms secure themselves by closing the mouth of the tube in different ways; for example, *Serpula*, *Spirorbis* and *Sabellaria* by opercula or structures connected with their own heads; *Sabella*, by the collapse of the lately formed mouth of the tube; *Pectinaria*, by a sand, mucus-made, minutely perforated appendage to the smaller end of the tube (a fact first noticed, I believe, by Dr. Pierre Fauvel); *Terebella littoralis*, to some extent, possibly, by the falling together of the beautifully filamented fans with which it decorates the mouth of its tube; *Sabella saxicava* (often, but not always, says Soulier), by the curious coiling up of its tube, like a watch spring, and uncoiling like the young frond of a fern (a sight which I first had the good fortune to see); but the defensive mechanism of the Onuphidæ is to me a new and exceptionally interesting method, and I am greatly indebted to Prof. Herdman, who, on one of the Liverpool dredging expeditions, first drew my attention to these worms, and to Dr. Allen and Mr. A. J. Smith, of the Plymouth Laboratory, who have kindly procured for me the living specimens with which I have recently worked.

Explanation of Plate.

Fig. 1. Tube of *Hyalinœcia tubicola*, natural size, from a photograph, showing V-shaped, anterior valves, *v*, and zigzag, posterior valves, *v′*. Intermediate markings are traces of old valves which have been removed by the worm when lengthening its tube to make more habitable space.

Fig. 2. Diagram, showing action of the protective valves, *v*, *v*, at the anterior end of the tube of *Hyalinœcia tubicola*. The arrow indicates the inrush of water closing the valves. They are, of course, raised and opened by pressure of the animal or water in the opposite direction.

Fig. 3. Diagram, showing action of the protective valves, v', v'', and v''', at the posterior end of tube of *Hyalinœcia tubicola.* The arrow indicates the inrush of water closing the valves.

Fig. 4. Diagram of the same portion of tube, demonstrating position of the same valves when the worm emerges, as shown by the arrow. The valves are then open, the membrane bulging in the opposite direction.

Fig. 5. Tube of *Onuphis conchilega*, natural size and in its natural position, the large terminal shell, *a*, at the anterior end, overhanging.

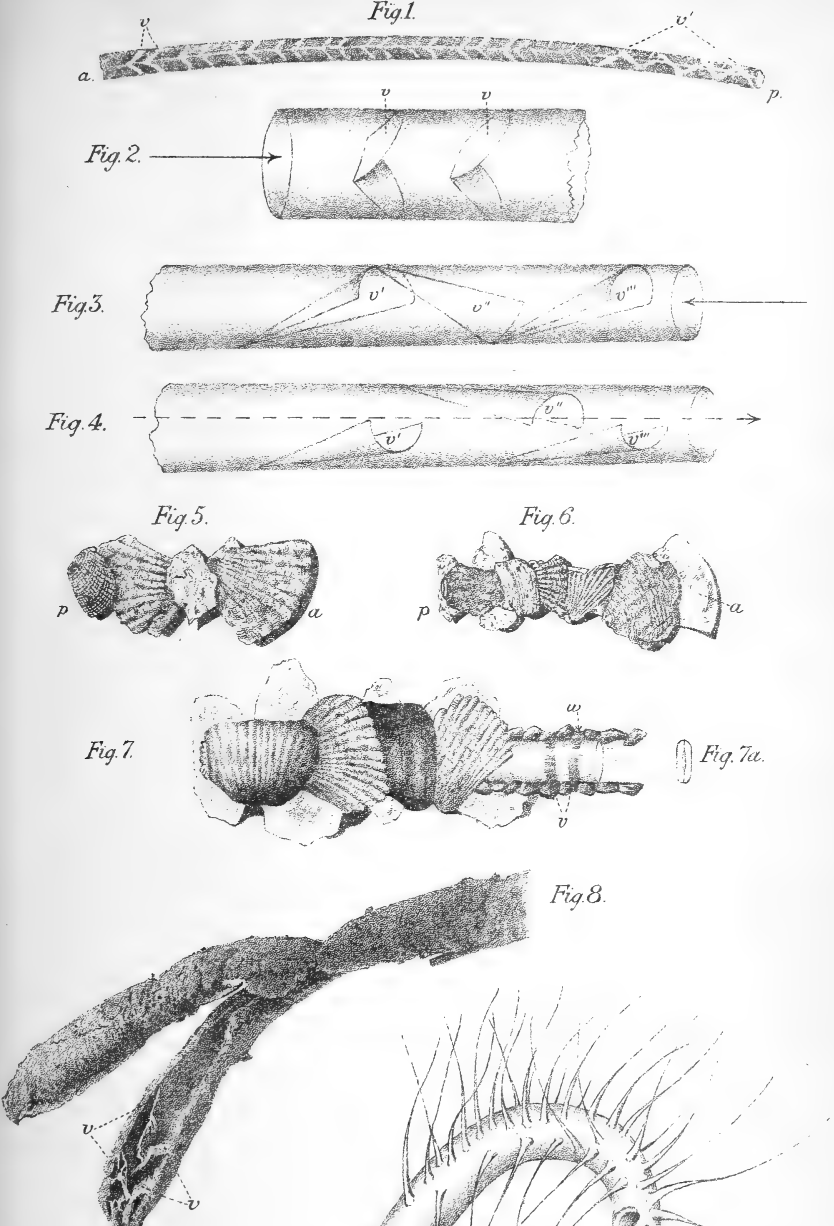
Fig. 6. Tube of same worm overturned. The large anterior shell, *a*, is shown lying on the sea-bottom, and at the posterior end, *p*, a small portion of membranous tube is visible.

Fig. 7. Tube of *Onuphis conchilega.* Semi-diagrammatic sketch, showing the internal, transparent, membranous tube, with its protective valves, *v*, and the sandy side-walls, *w*, exposed by treatment with acid. The end of the membranous tube is shown on the underlying shell at the other extremity. × 2.

Fig. 7*a*. End view of the above internal tube. The long axis of the ellipse indicates the edges of the valves. × 2.

Fig. 8. Terminal portion of tube of *Nothria pycnobranchiata,* split open to show the internal valves, *v*, *v*. From a photograph, slightly enlarged.

Fig. 9. Tube of *Nothria willemœsii,* showing external protective spines. Rough sketch from a specimen in the British Museum. Slightly reduced.



A.T.W. del. S.B. lith.

TUBE DWELLINGS OF ONUPHID WORMS.

St. Kilda Village and Bay.
(From a Photograph by Major Colquhoun. By kind permission.)

ST. KILDA AND ITS BIRDS.

By J. Wiglesworth, M.D., F.R.C.P.,
Member of the British Ornithologists' Union.

(Read December 12th, 1902.)

There is probably no corner of the British Islands which, ornithologically speaking, presents so much interest as the island group of St. Kilda. With the exception of the modified form of the common Wren, of which I shall have to speak later, there is, indeed, no species of bird peculiar to the place; for the recent spread of the Fulmar to Shetland, of which I gave a short account to this Society last session, has robbed St. Kilda of the pre-eminence in this respect which it formerly enjoyed, so far as the British Islands are concerned. St. Kilda is, however, the great headquarters of this bird in the British Isles, where alone it can be studied to full advantage; and it is besides the stronghold of another very interesting species of this order of birds, Leach's fork-tailed petrel, which though breeding sparingly in some of the islands of the Outer Hebrides, as well as in some of those of the west of Ireland, can nowhere else be regarded as in any way plentiful.

Moreover, the extreme abundance there of many of the common sea-birds which frequent our coasts furnishes in itself an ornithological feast not readily to be forgotten.

There is besides a certain romance and glamour about the place itself which adds to its fascination. The loneliness of its situation, perched right out in the bosom of the Atlantic some fifty miles from the nearest point of land; its magnificent ranges of precipices hardly to be matched anywhere else in the British Islands, which have for ages withstood the onslaught of the most furious Atlantic storms: the hardihood of its inhabitants, whose intrepidity and resourcefulness have won for themselves a footing in this inhospitable and isolated spot, all these combined with the marvellous wealth of bird life which flourishes there, furnish to the lovers of the wild and majestic in nature an irresistible attraction. I had long had a desire to visit this far-famed island, and an opportunity having presented itself last summer, I sailed from Glasgow, in company with my friend Mr. Newstead, in the s.s. "Hebrides," on the afternoon of June 2nd, and after a delightful sail up the west coast of Scotland, touching at several of the Hebridean ports, we finally cast anchor in Village Bay, St. Kilda, about 1-30 in the morning of June 5th. Mr. Newstead was unfortunately obliged to return home by the steamer "Dunara Castle," which came to St. Kilda four days after our arrival, but I waited for the return of the "Hebrides" on June 26th, so that I spent exactly three weeks on the island. During this time I occupied a small room in the cottage of Mr. Donald Ferguson, the head man of the village, to whom, and to his two sons, Alec and Neil Ferguson (the former of whom is in business in Glasgow) I was indebted for much kindness and attention, and readiness in imparting information. I had nearly a fortnight on end of stormy weather in the latter part of my stay, during which I was only once able to get out in a boat, but on the other hand, during the early part I got several beautiful days, which enabled me to go almost everywhere, so that on the whole I considered myself pretty fortunate in this respect.

St. Kilda is a much written about place, and an apology may seem needed for adding to the number of communications on the subject: but I have thought that a short account of the place and its people, and of incidents of life there, drawn almost entirely from personal observations, and from information collected on the spot, might present some points of interest, and serve as an introduction to what I have to say about the birds.

The island group of St. Kilda, consisting of St. Kilda proper, and of three subsidiary islands, Boreray, Soay and Dun, lies about fifty miles due west of the sound of Harris. The main island, St. Kilda proper, or Hirta, as it was formerly called, is about $2\frac{1}{4}$ miles broad, and $2\frac{1}{2}$ miles in extreme length from one point to the other. Boreray is situated about four miles to the north-east of the main island, Soay lies near its north-west corner, and is separated from it by a sound some 400 yards across, whilst Dun is practically a projection of the southernmost point of the island towards the south-east, being only separated from it by a narrow strait—the Dun passage—which can be crossed at extreme low water by jumping from boulder to boulder. The Dun forms a splendid breakwater against the southerly and south-westerly gales, and without it St. Kilda would probably be uninhabitable. There are also several isolated stacks, or rocky islets, which from an ornithological point of view, are of much interest, the chief being, Stacks an Armin and Lii, off Boreray, Soay Stack and Biorrach in Soay Sound, and Levenish, which lies about $1\frac{1}{2}$ miles almost due east of the point of the Dun. The best map of the island, and indeed the only authentic one, is that published by Mr. Norman Heathcote (1), who spent about two months there in the summer of 1899, surveying the islands, and to his careful work every visitor to St. Kilda stands much indebted.

St. Kilda is remarkably hilly—you cannot go anywhere without a climb—and there is scarcely a level spot in the whole of the island. With the exception of two bays, Village Bay, facing south-east, and West Bay towards the north-west, into which the valley called the Glen gradually drops, it is girt around everywhere with magnificent rock walls and precipices, the highest of which, that of Connacher, drops nearly sheer into the sea from a height of about 1,200 feet, but more generally the hills trend away in very steep grassy slopes until the cliff line is reached several hundred feet above the sea.

Connacher, however, is merely one giant amongst many, and the magnificent precipices of Soay and Boreray, some of which are not much inferior to it in altitude, are worthy rivals on the score of grandeur and picturesqueness. The latter two islands, indeed, are particularly rocky and precipitous, and can only be landed on in one or two places, and the ascent from the rocks to the grassy tops of the islands involves a good bit of stiff climbing.

The village is situated at the foot of a fine amphitheatre of hills on the north and east sides of Village Bay, where the land slopes gradually down to the sea, and is the only habitable spot in the islands. The little houses occupy a single curved line directly facing the sea, with a narrow, rudely paved "street" in front, which is separated by a low wall from the little patches of cultivated ground which slope away down to the shore of the bay. Here the land is terminated by a high bank and a rampart of large, rounded boulders, the size of which testifies to the violence of the winter storms, beyond which a small strip of firm sand is left exposed at low water, the only patch of sand round the whole of the islands. Above the village again the little crofts, with their patches of oats, potatoes, grass, &c., struggle up the slope for a few hundred yards, until they are separated from the general hillside by a long wall built to keep out the cattle and sheep. The hillsides, though affording good pasturage, present from a distance a decidedly bare appearance, which contrasts rather strongly with the bright green of the cultivated patches at their base; and as viewed from the bay in the evening light, when the sun has dipped behind the shoulder of the Sgail, the scene presents a somewhat sombre aspect. The houses now occupied by the natives (not counting one of the old ones) are sixteen in number, and are comfortable little solid stone structures, with zinc-covered roofs, built almost as it were into the side of the hill, the ground behind being nearly on a level with the spring of the roof. The houses, which are all alike, are of one storey only, and each consists of two chief rooms—kitchen and bedroom—separated by a little lobby, into which the front and only door opens; each room is a little over seven feet in height, and is lighted by a four-paned window. Besides these, there is another small room at the back of the lobby, which is lighted from the roof, and which is used as a storeroom and additional sleeping apartment. The houses formerly all had mud floors, but many of them now have cement floors in the kitchen and wooden ones in the bedroom, the walls and ceiling of which are also matchboarded. This serves as a protection against the damp, from which, owing to their position on the side of a hill, the houses are very apt to suffer. At the bottom of the "street" stands a two-storied cottage, which is occupied by the Factor during his annual visits to the island, and below this, close to the little pier, is the Manse, in immediate proximity to which stands the Church and Schoolhouse. Beyond this again, close to the shore, is a stone building, which is used as a general storehouse for feathers, dried fish, &c., for the whole of the village. This is placed immediately above the old landing-place on the rocks, where the St. Kildans from time immemorial landed and launched their boats, but which is now superseded by the little pier higher up the bay towards the village, which was only completed last year, and which has greatly improved the facilities for landing and embarking.

The present cottages were built about 45 years ago by the then proprietor of the island, Sir John MacLeod. Formerly the people lived in small oblong stone hovels, with domed, thatched roofs, which from their appearance have not inaptly been designated "bee-hive houses." Many of these houses still exist; they alternate with the ones now inhabited in the little line of the village street, and are now used as barns, storehouses and byres. One of them, however, is still inhabited by an old woman, named McCrimmon, the last of her race, who lives in it all by herself. These old houses are oblong structures, with rounded ends, built of large unhewn stones and boulders, the walls being about five to six feet in height and of great thickness—four feet, and even more; no mortar has been used in their construction, the interstices between the stones being filled in with soil. The roof, which is high-pitched and dome-shaped, is set back some two feet or more from the outer line of the wall, and is constructed internally of timber, which is thickly covered with turf and coarse thatch, the whole forming a distinct though oval dome, which when looked at on end has much the appearance of a gigantic beehive. Interiorly the space was divided into two by a wooden or stone partition, on one side of which the domestic animals were kept in winter, and on the other side was the general living and sleeping apartment, the beds being built into the side of the wall. The solitary one of these houses now occupied, already referred to, presents us at the present day with a picture of the ancient mode of life. The centre of the living apartment was occupied at the time of my visit by a peat fire, divided off from the rest of the floor by a low stone coping, and immediately over this a chain was suspended from the roof, to which the kettle or cooking pan was attached. There was no chimney, but two holes at the top of the stone wall just below the spring of the roof, allowed the smoke to gradually escape after filling the room. The whole place was very dark, and even when one's eyes had got accustomed to the darkness it was difficult to distinguish objects clearly. The walls and every part of the room were begrimed with the dirt and smoke of years, and the whole place was wretched in the extreme. Yet in such places as these all the people lived less than half a century ago. The contrast between the old and the new houses was indeed sufficiently striking, and one could not fail to realise forcibly the kindness and liberality of the then proprietor of the island, who, by giving the people decent dwelling-houses, lifted them out of a condition of semi-barbarism, and placed the elements of civilization within their reach. On the hillside immediately behind the line of houses, an oval space, enclosed by a stone wall, marks the site of the little cemetery, where many generations of St. Kildans lie in their nameless graves, which are marked simply by a rude stone taken from the hillside, without inscription, placed at the head and foot of each. The cemetery is in a very neglected state, the graves being almost hidden by a rank overgrowth of nettles and flags. Tradition has it that this cemetery marks the site of an ancient temple, but the only ground for this belief that I could discover was, that some large stones, apparently belonging to a building of some size, were said to have been unearthed here in the course of excavations.

Next to the houses, the objects that most arrest the attention of the stranger are a number of little oval stone structures, which are scattered in all directions over the hillside, and even on the tops of the hills. They are extraordinarily numerous, there being, it is said, some thousands of them. These are the cleits, which are used by the islanders for storing their peat, hay, corn, &c., and in the larger ones the sheep are frequently kept in winter. They vary a good deal in size, the larger ones being those nearest the village. They are constructed with no little skill, the walls being of boulders cleverly fitted together without mortar, the superimposed courses gradually approaching each other as they rise higher, until the topmost ones are sufficiently near together to be bridged over with flat slabs of stone. The top is covered with a thick layer of turf, forming a rude dome-like covering. It is easy to recognize in the construction of these little buildings the hand of the architects of the beehive houses.

St. Kilda possesses scant monuments of antiquity, but a few interesting relics of pre-historic times have escaped the ravages of time. The most interesting of these is an underground dwelling on the hillside a little above the village, which goes by the name of the "Fairy House." It is a low passage-like structure, built into the hill, the walls being composed of large blocks of stone, and roofed over with large slabs. It is about 20 feet in length from its present entrance, some three feet in breadth about the middle, narrowing towards the roof, and about four feet in height. Leading out of it on one side is a small oval chamber roofed with slabs of stone, and the remains of a similar chamber now roofless and filled in with rubbish just outside the present entrance, shows that the building was formerly of greater extent than now. This structure, which was to a great extent covered up and filled with rubbish, was excavated by Mr. Kearton (2) at the time of his visit, and a spear head and other objects of interest supposed to belong to Viking times were discovered in it.

That this building represents an underground dwelling-place of some of the original inhabitants of the island is not improbable, and it is likely enough that other similar structures exist in the island awaiting disinterment by the shovel of the archæologist.

On the island of Soay stands a small stone structure, which goes by the name of the "Altar." It is composed of flat stones laid one above the other in regular courses, though those at the top are now very uneven, is of rectangular shape, and measures now about 6 feet by 5 feet 3 inches by 3 feet 6 inches in height. The origin of this little structure is lost in hoary antiquity, but it has without doubt been constructed for a definite purpose, and its use was probably that indicated by the name attached to it.

One other relic of bygone times may be mentioned, namely, the so-called "Fort," near the point of the island of Dun. The extremity of this island-promontory consists in great part of a chaos of rocks and boulders, many of them of prodigious size, which are scattered about in all directions in the wildest confusion. These rocks form a natural fastness, tenanted now by hordes of Puffins and Razor-bills, the comparative security of which had evidently been taken advantage of by the inhabitants in remote ages as a refuge from their enemies. For, on the only vulnerable side of this retreat, a wall has been built leading down the hillside from the rocks above to the cliffs below, which constitutes the so-called "Fort." It is constructed of large flat stones, laid one above the other in more or less uniform courses, and would doubtless in ancient times have served as an efficient rampart. Secure from any attack on the seaward sides by the unscalable nature of the cliffs, the aborigines of the islands might well have defended themselves here against the incursion of an invading horde.

The number of natives resident in the island at the time of my visit was 76, but in the course of my stay an addition was made to the population—the first for over a year—bringing the total up to 77, which makes an average of 4·8 persons to each household. The men are a sturdy, vigorous race, averaging perhaps a little under the middle height, but thick set and strong looking. There is a dark and a light type, the latter predominating. The women are big framed and strong, and apparently age early, which is not to be wondered at, considering the hard lives they lead. They are very hard working, and carry remarkably heavy loads on their backs. Every morning during the spring and summer some of them traverse the ridge which runs across the island to the "glen" on the opposite side, where the milking ewes and cows are kept on account of the richness of the pasturage, returning in the evening with sacks full of freshly-gathered grass on their backs: whilst in the early morning, before they leave, and in the evening after their return they are busy with household duties. The people as a whole are kind and hospitable; they are civil to, but apt to be somewhat suspicious of, strangers, and as their demeanour is rather impassive, they do not always impress visitors altogether favourably. Personally I found them a very civil, obliging lot, and perfectly honest. They are exceedingly temperate, and rarely quarrel. They are very zealous in the performance of their religious duties, and attend the services of their church with great regularity. I attended one of these services one Sunday morning. This was, of course, conducted in Gaelic, of which I did not understand a word, and a sermon of about an hour's duration in that language was, therefore, naturally not very informing. The service was of the usual Highland character, but to a stranger the Gaelic singing had a decidedly weird effect. After the service was over the women all got up and left the church before any of the men stirred from their seats—an interesting survival of a very ancient custom. The women were all in their Sunday (and holiday) attire, wearing bright coloured shawls and gaudy coloured handkerchiefs over their heads, red being the predominating colour. The Sabbath is very strictly observed by the natives, no work of any kind being carried out on that day if it can possibly be avoided. I do not wish to imply from the foregoing that these people have no faults, but I am stating my own experience of them. It is the etiquette of the place to shake hands with the natives every morning at least, and the hearty hand-shake of a St. Kildan is a thing to be remembered.

Nothing is known with certainty as to the original inhabitants of St. Kilda, but there can be no doubt that the present natives are the descendants of immigrants from other of the Hebridean islands—Skye, Lewis, Uist, &c.—as might, indeed, have been anticipated. It is an undoubted fact that some of their ancestors were persons who were banished from these islands for various offences, or who found it convenient to anticipate justice by leaving them; but that all the natives are so descended (as some writers have implied) seems to me very improbable. The natives say that the island was at one time much more fertile than now, and grew much more corn, and there is some historical evidence in favour of this statement, for in Martin's (3) time the island supported a much larger population than it does at the present day. There would consequently formerly have been greater inducements for people to settle there than exist at present.

There are now only six surnames in the island—Ferguson, Gillies, MacQuien, MacDonald, MacKinnon and MacCrimmon, and if we except the last-named, which is represented by one old woman only, at whose demise the family will become extinct, there are only five. This, of course, indicates a good deal of blood relationship amongst the existing population, but the ill effects of in-breeding are not so apparent as might have been anticipated, and are less evident than in some other isolated portions of the British Isles with which I am acquainted. All the older people speak Gaelic, and nothing else; but the younger generation, having been taught English in the school, can converse in that language, and some of the young men speak it very well. There are now nineteen children between the ages of 5 and 14 attending the school, and there are eight in the place under five years of age. Small families are the rule in St. Kilda, but this is in part due to the ravages of that terrible disease, *Tetanus neonatorum*, which up to recent years carried off a very high proportion of the infants. Now, however, thanks to the exertions of the late minister, Mr. Fiddes, who was instructed in the requisite antiseptic measures to adopt by a Glasgow surgeon, this dread disease has been banished from their midst. There is no doubt that the disease was conveyed by direct infection in uncleanly wrappers used to swathe the infants in, and no child was safe until the cicatrization of the umbilical cord, about the eighth day, barred the channel by which the tetanus bacillus entered the system. Much ingenuity has been expended by various writers in discussing the causes of the prevalence of this remarkable disease; but a simple explanation may be found in the damp mud floors of the houses in which the people till lately lived. The tetanus bacillus, as is well known, lives in damp soil, and there can be little doubt that it was in this way introduced into their tenements, and handed on from one child's clothing to another, owing to the want of proper cleanliness, even after the later improvements in their dwellings, such as cemented and boarded floors, rendered them less liable to its inroads.

Most people have heard of the "Stranger's cold" which used to infect the whole population of St. Kilda whenever a boat's crew arrived from the mainland, even though the strangers might be to all appearance free from it themselves. This fact is perfectly well attested by Martin (3), Macaulay (4), and others; though now, owing to the much greater frequency of communication with the mainland, this phenomenon is not nearly so marked, the disease having become more or less endemic in the place. It shows clearly that the micro-organisms which produce catarrh may exist in the nasal passages of individuals who are not at the time obviously suffering from any affection of this sort. And it furnishes an interesting illustration of the susceptibility of an isolated community, like that of the St. Kildans, to the diseases incidental to civilization when these are introduced amongst them. The most striking instance of this is seen in the terrible epidemic of smallpox which depopulated the island early in the eighteenth century (about 1724). It originated by a native of Uist, who had settled in St. Kilda with his family, going over to the "mainland," as the Hebridean islands are called by the natives, to visit his relations. There he contracted smallpox and died, but his clothes were sent back to his family in St. Kilda, and the infection conveyed in them started the epidemic. There were at that time twenty-five families in the island, and when the epidemic subsided there were (to use the expressive words of the tradition) only five houses out of which smoke issued, all the members of the other twenty families having perished, as well as several members of the surviving ones. It happened that just before the outbreak, at the end of

August, twelve men had gone to Stack an Armin to catch gannets, and as there were not enough men left on the island to man a boat to take them off, they were left on Stack an Armin all the winter, and were only relieved when the Factor's boat came the following summer. That they were able to support themselves in such a place says much for their hardihood, but they were put to great straits, and had it not been that one of their number had a rusty nail with him, which being fashioned into the shape of a fish-hook, enabled them to catch fish after the birds had left, they could hardly have survived. As it happened, however, they undoubtedly owed their lives to being left in this position of isolation. The island was repeopled almost entirely from the survivors, the Fergusons being the only family which has settled in the island since that time. The frightful mortality experienced in that epidemic shows very clearly what smallpox is capable of when it breaks out in a community unprotected either by vaccination or by previous experience of the disease. In all civilized communities which have been in contact with certain diseases for numbers of generations, a process of continual selection as regards those diseases has been, and is, going on, the individuals which are most susceptible to those diseases dying off, and the race being continually recruited from those who are most resistant to them. But an isolated community like that of the St. Kildans, not having undergone any such weeding-out process, the members of it present a virgin soil for the growth of the bacilli, which initiate the various infective disorders, and these diseases are hence apt under such circumstances to assume an unusual virulence. If a disease such as measles were ever imported into St. Kilda, it is to be apprehended that the rate of mortality from it would be a high one.

The dogs of St. Kilda are quite a feature of the place, and a not altogether pleasing one. They are of a mongrel collie type, warranted to do as little work and to make as much noise about it, as possible. They are relatively very numerous, there being no less than thirty-four in the island, an average of 2·1 to each house. They are kept ostensibly as sheep dogs, an office which they perform sufficiently badly, their only idea of catching a sheep being the pristine one of worrying it, so that their teeth have to be specially blunted to prevent the damage that would otherwise ensue. Every young dog, therefore, when he attains the age of six months, has his canine teeth broken off on a level with his gums with a hammer and chisel, and all the others are blunted by being filed down, which filing process is repeated two or three times a year when the dog is young, the intervals being gradually prolonged up to the age of five years, after which the operation is no longer considered necessary. They are most unpleasant in their attentions to strangers, and though I believe they do not bite, the persistent snarling and barkings do not exactly add to one's comfort. It was not till quite towards the close of my visit that they began to cease to manifest active hostility towards me; I cannot say that even then they showed any signs of friendship, but it was something to be tolerated, and to be enabled to take one's walks abroad without exciting the attentions of the whole pack. If they would only conduct themselves with some propriety at night, one might endeavour to feel not too uncharitably disposed towards them; but when one is deprived of sleep at night, as well as worried by day, by their persistent howlings, one can only vote them an unmitigated plague. Fortunately, however, it is not every night that they offend in this way. Whenever a boat of any sort comes into the bay, even one of the boats of the islanders returning from a day's fishing or a fowling expedition, they all with one accord rush down to the shore to meet it, and it is a most ludicrous sight to see the whole pack capering about the little pier and landing slip on such occasions, and barking for all it is worth. But the arrival of a steamer makes them go fairly mad with excitement, and when this occurs at night, sleep is quite impossible, and it takes them a long time to get quieted down again. They do, however, really serve one useful purpose, and that is by acting as scavengers. The bodies of birds which had been skinned in the evening and thrown over the low wall in front of the cottages, had always disappeared by the following morning, and the basins into which eggs had been emptied of their contents were cleared up in the twinkling of an eye. Such time indeed as is not taken up with quarrelling among themselves, is spent in prowling about seeking what they may devour, and in a community where sanitary arrangements are virtually non-existent, and where the refuse of birds and eggs is constantly littering about, a function of this sort is not without its value in the body politic.

The wealth of the St. Kildans, if one may so style their chief means of livelihood, lies mainly in their flocks and their birds, for the produce of the little crofts, apart from the potatoes they grow, chiefly goes to the support of the few cattle which they rear. Of late years they have taken to do a certain amount of fishing, both for home consumption and for export, but the sheep and the birds furnish their main support. Roughly speaking, they own altogether about 1,000 sheep, 700 of which are on the home island, and 300 on Boreray. The rams are kept on Dun during the spring and summer months, and in November, when these are taken off, the lambs are put there to fatten. An annual capitation fee, varying from sixpence to a

Village Street, St. Kilda. Cutting the Wool off the Sheep.
(From a Photograph by Mr. R. Newstead. By kind permission.)

shilling is paid to the landlord for each sheep grazed. On Soay there is a breed of perfectly wild sheep belonging to the Chief, but of this more anon. The sheep are, of course, valuable for food, and in the spring the ewes are milked and a coarse sort of cheese made from the produce; but their chief value lies in the wool from which a good sort of light tweed is made, of similar class to the well-known Harris tweeds. The sheep are not shorn in the ordinary way, but the fleeces are cut off in very primitive fashion by means of a pocket knife. The whole process of manufacturing the wool into cloth is carried out on the island, and spinning and weaving constitute the chief winter occupation of the inhabitants. As soon as the Fulmar harvest is over, towards the end of August, the looms are got out and put in order by the men, and all who can do so are busily engaged working from early morning till late at night at this, their staple occupation. Part of the cloth is given to the landlord in payment of rent, or exchanged for meal and groceries; but they have now an independent sale for it, which is a sensible factor in the increasing prosperity of the people.

The improved economic conditions resulting from the development of the cloth industry and from the fishing which is now done, have rendered the produce of the birds of less account than formerly, but this is still an important factor. Up to about twenty years ago enormous quantities of feathers were exported as payment for rent, or in exchange for meal and other necessaries, and immense numbers of birds were killed for the sake of their feathers alone. The young people of both sexes used to camp out for weeks on the subsidiary islands during the summer months, and would catch hundreds, and even thousands, of birds, chiefly Puffins, in a day, the carcases of which, after plucking, were thrown into the sea. Stacks Lii and an Armin were similarly visited by the men for the sake of the Gannet feathers. The feathers, indeed, were at that time their chief source of livelihood. Having, however, now other means of support, and the time of the men being now more taken up with fishing, it no longer pays them to go through the hardships which the collection of the feathers entailed, especially as the price is now very low, and the slaughter of birds for this purpose only has now been discontinued. Considerable quantities of feathers, mostly those of the Fulmar, are however still exported, but these must be regarded rather in the light of a by-product of the Fulmar harvest, as these birds are killed more particularly for food and for the sake of the oil. Boiled Fulmar is looked upon as a delicacy by the natives, but though I sampled one, I cannot say that I was much enamoured of it, as to me it had rather a sickly, insipid taste: it was better roasted. Puffin, I found much more palatable: in fact, roasted as the natives do it, the bird has a distinct gamey flavour, and is by no means bad. Considerable quantities of these birds are consumed as food by the natives, but they are not eaten to nearly the same extent as formerly. The method of cooking them is, after plucking, to split them down the back from one end to the other, when, after cleaning, they are opened out flat, and being placed in an upright position on the floor of the hearth, are roasted in that way before the peat fire. When they come to table they have something of the appearance and flavour of kippered herrings. Guillemots and Gannets are also captured for food when they arrive in the spring, but the great raids on the young Gannets in the autumn for the sake of the feathers and oil have been discontinued during the past few years.

Concurrently, however, with a diminution in the number of birds killed for the sake of the feathers, a trade has sprung up in the eggs, which bids fair to assume considerable dimensions. Eggs, of course, have always been largely taken by the St. Kildans for the purpose of food, and are so still, but of late years the trading collector has got a foothold in the place, and the number of eggs now exported annually to supply the insatiable demands of the trade seems destined to do more damage to the bird population of St. Kilda than the natives would ever have effected if left to themselves. A fair number of eggs is also sold as bric-a-brac to the tourists, who land for a few hours from the Glasgow steamers, which visit the island during the summer months. Were the demands of the trade confined to the eggs of such birds as the Guillemots, Razor-bills and Puffins, it would not be a matter of much consequence, as these birds are sufficiently numerous to hold their own in spite of it; but when it comes to dealers giving unlimited orders for Fork-tailed Petrels' eggs, at prices which set the whole male population of the island on the alert to dig out every Petrel burrow they can possibly come across, one cannot but feel considerable anxiety as to the future of this interesting species. The St. Kildan Wren, too, is hunted down remorselessly for the sake of its eggs, for which high prices are paid.

The cliffs and rocks of St. Kilda proper are divided into sixteen lots, one for each of the sixteen houses, and no native is allowed to take birds or eggs from any "lot" other than his own. When, however, expeditions are undertaken to the subsidiary islands and stacks, it is the custom for the produce of the day's work to be divided up equally amongst the sixteen households.

Every one who has written about St. Kilda has expatiated on the wonderful skill displayed by the natives in climbing the rocks, and the daring exploits performed by them in following their favourite calling, though many of the accounts are tinged with no small amount of hyperbole and exaggeration. There can be no doubt, however, that as clifters and cragsmen they are unsurpassed, and it was a treat to see them negotiating difficult rock faces where but little foothold or handhold could be obtained, or walking with perfect ease and celerity upon narrow ledges overlooking tremendous precipices. They are remarkably sure-footed, and their heads seem to be quite unaffected by any amount of vertical depth below them. They are not, however, foolhardy, but take all reasonable precautions, never climbing alone, and always going roped together whenever particular caution is required. The usual method adopted when descending the steep grassy slopes, or less difficult cliffs, is for two men to go roped together, the first man working the fowling rod, whilst the hind man supports him, and guards against a slip, though cases have occurred, as in Alpine accidents, where the second man has been pulled over by the first slipping, and thus two lives have been sacrificed instead of one. The more difficult places, however, are negotiated by three men with two ropes, which are worked by two men at the top of the cliff, whilst the third is lowered down with one of the ropes tied round his waist, and holding the other as a guide. Before starting on their big expeditions the ropes are carefully tested. It must not be supposed, however, that all the climbs in St. Kilda are the desperate undertakings which some writers make out. Many of them can be undertaken with proper precaution by any one with a fair knowledge of clifting. There remain, however, many really difficult places where few people would care to follow the natives. Of these Stack Biorrach in Soay Sound is looked upon as one of the crack climbs of the place, though the old story about a man not being able to get a wife until he had proved his prowess by accomplishing this feat may, like the story of the Lovers' Stone, be dismissed as a figment of the imagination. Not even all the St. Kildans, indeed, can face Stack Biorrach. There are at the present time in the island only five men who have climbed it, and of these only two could do it now, the others being elderly men; but from what I saw of the exploits of some of the younger men, I should say that it would not be long before this list was added to. Fatal climbing accidents are rare, and there seems a unanimous consensus of opinion that such accidents are less frequent now than in former years. The last one occurred about forty years ago. As to the cause of this diminution in the number of accidents, various opinions have been put forward, such as the use of better ropes, and the exercise of greater care. It is a fact that in ancient times ropes made of plaited straw were used for climbing, but the death of a man who was lost on the Boreray cliffs by a rope of this sort giving way caused the use of these to be discontinued. The straw ropes were succeeded by others made of raw cowhide, and these in turn gave way to horsehair ropes, which were in use until a comparatively late period, when they were superseded by Manila ropes, which are now exclusively employed. No fatal accident has, however, been known to have taken place owing to the giving way of a rope since the one just mentioned, so that the improved quality of the ropes cannot have been the main factor in the reduction in the number of accidents. The natives themselves attribute this diminution to the greater care exercised, and to the fact that the practice of going alone to the cliffs, which was formerly in vogue, has now been discontinued. Whilst giving due weight to these views, I doubt if they express the whole truth in the matter. I should think it very probable that for several centuries a process of natural selection has been in progress, causing on an average those men to survive whose steadiness of nerve and sureness of foot had safely carried them through all the perils of their calling, whilst their companions who were less well endowed in these respects, were not unfrequently eliminated. The youth of 17, for instance, who fell from the top of Oisaval forty years ago when catching Puffins, left no descendants to inherit the defect of nerve or unsteadiness of foot, which caused him to meet his death; and the same thing must frequently have happened in the past history of the islanders. The race, indeed, here as elsewhere, has been continually recruited from those who were best fitted to their environment, and a more perfect adaptation has therefore resulted in fewer deaths occurring from failure of adjustment.

The St. Kildans are as expert in the art of managing their boats as they are in climbing the cliffs. I do not mean to say that they are specially expert as sailors, but the skilful manner in which they bring their boats up to the rocks, and land and re-embark in the face of a heavy swell, where few sailors even would care to risk their boats, is remarkable. Long practice, however, has enabled them to judge so accurately as to the extent to which they can venture, and so cleverly do they manage the business, that though the boat may appear to be in imminent risk of being smashed on the rocks, such accidents are nevertheless very rare. The difficulties, of course, vary greatly with the state of the wind and sea, but even in the finest weather the restless heave from which the Atlantic is never free, causes a ceaseless swell to beat upon the rocks, and a really calm landing is a very rare event. Although, of course, landing is frequently effected with no particular difficulty, it may be said generally that the process of landing and re-embarking are usually the most important events of a day's expedition, and they often occupy a good deal of time. A notable point, and one not unfrequently attended with danger, is the rapid manner in which the swell often rises, so that, it may be, though the landing has been carried out without difficulty, the process of re-embarking is effected only with the greatest trouble, and may even be quite impossible. In the latter case the natives, with ropes round their waists, have to take to the water, and be hauled through the surf to the boat, a contingency of some rarity, but which nevertheless occasionally happens. When approaching the rocks, if there is any sea on, the natives generally bring the boat broadside on, and whilst some of the number keep the boat off with oars and boat-hooks, one of the crew takes the first opportunity which presents itself of leaping on shore. The men never land without having a rope securely fastened round their waists, so that in case of a slip into the sea, they may be dragged back into the boat, for strange as it may seem, not one of the islanders can swim, nor is there any tradition amongst them that a native-born St. Kildan ever acquired the art of swimming. An accident in landing, however, very rarely happens. Before landing, also, the boots are invariably removed; some of the natives climb the rocks in their bare feet, but more commonly they wear a pair of woollen socks; and I found it very necessary to imitate the example of the natives in this respect, for the woollen socks enabled one to walk with ease and safety in places where the wearing of boots would have been highly dangerous.

On the morning of our arrival at St. Kilda, as soon as the departure of the steamer enabled a boat to be obtained, we took advantage of the calm weather prevailing to visit Boreray—a two hours' row from Village Bay. There are only two or three places on this rocky island where a landing can be effected, and a stiff climb up the rocks immediately commences, which finally lands one on the grassy slopes which constitute the top of the island. Here some 300 sheep are grazed, for the pasturage of which a charge of 6d. a head is made by the proprietor. These are left a good deal to themselves, and naturally get pretty wild, and some of them get lost over the cliffs every year. The natives make a stay of a few days in the island every summer for the purpose of shearing the sheep, living during that time in little primitive, partially underground, huts, which have been constructed for their shelter. They also go in the autumn to catch a few sheep to salt down for winter food. Boreray is the great headquarters of the Fork-tailed Petrel, which still nests plentifully in burrows in the light turfy soil of the hillside, and it was a pleasant experience making the acquaintance of this interesting little bird at the nest. As mentioned before, these eggs have now unfortunately a market value. Two boat loads of natives went over to the island the day we were there, for the express purpose of collecting these eggs, and it was a melancholy sight to see upwards of a dozen men and boys on their knees on the hillside, busily engaged in tearing up the turf in search of the nests. It is a pity that the traffic in eggs of birds of this kind cannot be stopped, as the number of these eggs taken annually by the natives must in time seriously jeopardise the existence of this species, especially as the bird apparently only lays once. Boreray is also famous for its Puffins, which breed there in countless hordes, whilst the magnificent precipices on its western and north-western sides furnish nesting sites for innumerable Gannets. Coming home in the evening, we experienced an adventure, which might have had decidedly unpleasant consequences. On our way down the rocks to the boat we delayed somewhat over getting a photograph of a sitting Fulmar, and had not paid much attention to a sea-fog which had gradually been settling down, but by the time we had re-embarked and got fairly started, this had become so thick that objects could not be distinguished clearly above 100 yards away, and the horizon became more and more contracted as we proceeded. The other boats that had been at the island had left before us, and were nowhere to be seen. We soon lost sight of Boreray, and had nothing to steer our course by, for I found, to my surprise, that the men had brought no compass with them. The only thing, indeed, the men had to go by was the direction of the wind, which was very light, and my enquiry as to how they knew the wind had not changed since the afternoon failed to elicit any satisfactory response. Two hours passed, and we ought to have landed in Village Bay, and yet for aught we could tell to the contrary, we might have been miles from any land. There was a death-like silence over everything. A Fulmar would frequently sweep by in its silent ghost-like fashion, and little parties of Guillemots would pass us in their bustling flight, but they were not all going the same way, and gave us no indication as to the direction of the land. It seemed at one time quite on the cards that we might have to pass the night at sea, and as our boat was a small one, and quite unfitted to stand any weather should any wind have got up, and as we had no provisions left, the prospect was not a pleasant one. At length, during one of the periodical restings on the oars, a sharp-eared lad in the boat thought he heard a sound as of surf on the rocks, and though the sound was not audible to the rest of us, we altered our course in the direction indicated, and after rowing for some time longer the roar of surf became unmistakable; a little more and the giant cliffs of Hirta suddenly loomed up under our bow. The men at once recognised the spot, and we had then only to follow the line of the cliffs round, until we were safely landed in Village Bay at 9.30 p.m.—about $1\frac{1}{2}$ hours over our time. We had gone a good mile out of our course to the westward, and had we steered two or three more points in the same direction, we should have rowed about parallel with the island, and would probably have missed it altogether, in which case morning might have found us on the broad Atlantic, out of sight of land, and with but small chance of being picked up by any passing vessel, as St. Kilda lies out of the usual track of steamers. I mentally resolved that if we went to Boreray again, I would take care to see that there was a compass in the boat.

The next day an expedition was organised for Soay, but when we got to Soay Sound there was such a heavy swell rolling in that it was found impracticable to land, so we proceeded through the Sound, passing Stack Biorrach, and after some little difficulty succeeded in landing on the lee side of Soay Stack. The rocks here for the first twenty feet or so were pretty perpendicular, but when this portion was surmounted the rest of the climb was quite easy. Owing to the stormy weather which had till lately prevailed, the natives had been unable to effect a landing on this Stack that season, previous to my visit, and so the birds had been undisturbed. Many Fulmars were sitting on their scanty nests in the angles of the rocks, and saluted me with their usual discharge of oil, as I ascended. Numerous Guillemots were sitting in little colonies on projecting angles of the rocks, and the eggs lay thickly scattered in these situations. The ledges here sloped somewhat inwards and downwards, and in the hollows thus formed rain-water had collected, and some of the eggs had rolled down into these little pools of water, and had thus become lost to their owners. A single nest of the Great Black-backed Gull, with three newly-hatched young, occupied a flat piece of turfy ground near the top. My stay on the Stack was somewhat curtailed owing to a break in the weather and the setting in of steady rain. The descent was a very different business to the ascent, as the rain had made the rocks so slippery that progression was by no means an easy matter. The first care of the men when they came to a convenient place, was to transfer to the boat a basket of eggs which had been collected. This was effected very cleverly by fastening the basket to the middle of a long rope, one end of which was held by the men on the rocks, and the other by those in the boat, which was tossing about in a very lively manner some 30 or 40 feet below. The rope was kept very taut, and the basket was gradually hauled into the boat in that way, and though I fully expected to see the whole thing smashed, it arrived safely at its destination with its contents almost completely intact. The getting down the last 20 or 30 feet of cliff was a ticklish business, as the rocks were as slippery as glass with the rain, and it was necessary to proceed with the greatest caution. A greater difficulty presented itself when we reached the bottom, and that was how to get back into the boat. The swell had risen so much that the surf was running up the rocks some twenty feet or so at the spot where we had landed, so that we could not approach the place, and had to make a detour. The boat was rising and falling with the swell through a distance of about a dozen feet, and it required all the exertions of the men in it to prevent it being stoved in against the rocks every time they approached to take us off. It looked very much as if we should have to adopt the last resort of the St. Kildans, and take to the water and be hauled through the surf to the boat. At length, however, a favourable opportunity for a jump occurring, I landed safely in the boat, after a drop of about six feet, and the other men followed suit as soon as a chance presented itself. This was the most difficult re-embarkation I had all the time I was at St. Kilda, and I doubt if any men other than natives of the place would have taken us off the Stack in such a swell as was running, for the danger of smashing the boat on the rocks was by no means a slight one. We continued our row home along the north side of the island, thus completing the entire circuit of the main island and Dun, and having put out fishing lines as we returned we were able to enjoy some delicious fish for supper.

Three days later I succeeded in landing on Soay Island without the least difficulty; it was in fact the easiest landing I had during my stay at St. Kilda, which was all the more surprising as Soay is certainly not celebrated for facility of access. There was a very strong wind blowing from the north, and the explanation of the smoothness of the water on the lee side of the island appeared to be that the north wind had smoothed down the swell on the opposite side, so that the landing was more easy than it would have been on a perfectly calm day, when the normal swell would have been able to assert itself. Soay is remarkably precipitous, and the climb up the rocks commences immediately on landing. The island is celebrated for its breed of wild sheep, and for the prodigious hordes of Puffins which swarm over its grassy slopes, and tenant also every available nook amongst the rocks and boulders. It is, moreover, the great head-quarters in our islands of the order *Tubinares*, all the British breeding species of birds belonging to this order nesting there plentifully. Manx Shearwaters are common, though difficult to obtain. Fork-tailed Petrels are plentiful, and Stormy Petrels probably not less so; but it is, of course, very difficult to estimate the number of such nocturnal birds. I should greatly have liked to have spent a night on the island for the purpose of observing these birds, but the weather was never settled enough to justify the risk, for it might have meant being imprisoned there for a fortnight or more. Fulmars are extraordinarily abundant. There is a magnificent range of precipices on the north side of the island, which with its rock walls and grassy slopes must be upwards of a thousand feet in height, which is one vast colony of these birds. As I looked down on it the prodigious number of birds constituted a wonderful spectacle. All available ledges and grassy slopes were occupied by large white dots, which the glass resolved into sitting Fulmars, and the crooning noise arising from thousands of throats rose up as a hoarse murmur. The air also from the level of one's eye right down to the sea was full of flying Fulmars, passing and repassing in all directions, with their wonderful buoyant flight, which could be seen to exceptional advantage from the elevated position which I occupied. It was a sight never to be forgotten.

The Soay sheep are an interesting breed of small, active animals, some 400 in number. They are perfectly wild, and cannot be approached within about 100 yards without careful stalking. Their prevailing colour is a light brown, but a few are almost black, and some nearly white. The rams have well-developed horns. They are very lithe and agile, and leap from rock to rock, and run down steep rock faces with ease and certainty, just after the manner of chamois. The St. Kildan dogs are no match for these sheep in fleetness of foot, and can never overtake them, so that their capture has to be managed by stratagem. To effect this they are driven by dogs to certain places in the island, where they are completely hemmed in by rocks and cliffs, and cannot escape except by going over a lofty precipice. Not very rarely the sheep, when thus cornered, chooses the latter alternative, and is, of course, killed. But generally when they find themselves in this predicament, they double back on their pursuers, and the dogs take the opportunity thus presented of seizing them as they rush past. Being so wild they are never shorn, but the natives sometimes collect the wool which is naturally shed, and mix it with the wool of their own sheep when manufacturing the cloth. Two rams were captured the day I was there; one, in particular, a beautiful, shapely animal, with a soft, dark brown coat, just freshly acquired. When captured their fore and hind legs are tied together, and they are slung over a man's back, and thus carried to the rocks, down which they are lowered with a long rope into the boat. All these sheep belong to the landlord, who charges the natives the small sum of half-a-crown for each animal taken off the island. The origin of the Soay sheep takes us back to an interesting chapter in St. Kildan history, as set forth in the traditions of the place. The islands have not been in continuous possession of the family of the present proprietor—MacLeod of MacLeod—although the original ownership by this family dates back for several hundred years. Towards the latter part of the eighteenth century, however, it having been found necessary to part with a portion of the family estates, St. Kilda was sold, and it eventually passed into the possession of a Mr. Hume. That gentleman leased the island to his factor, who was resident in Harris, and this man appears to have used very coercive measures towards the natives of the island in order to squeeze as much rent out of them as possible. It is terrible to think how, in those days of complete isolation, the people must have been at the mercy of an unprincipled landlord. The then lessee of the island took all the grain he could lay his hands on, except such as the people hid. He used to go over to the Glen where the women milked the ewes, and take possession of the cheese they were making. He also claimed every seventh lamb as his own, and these lambs being placed on Soay, were allowed to go wild there, as the natives would not trouble to look after them. This is how the wild Soay sheep originated, and it is this curious circumstance which has preserved to the present time the breed of sheep with which St. Kilda was stocked in the eighteenth century, and which was doubtless the same as that which was generally spread over the western islands at that period, but which has now been entirely supplanted by the introduction of new and improved forms. But to go on with the story. There was at that time in the island a Missionary named Alexander MacLeod, who had a son who had gone into the army and risen to the rank of Colonel. The natives in their extremity went to this Missionary, and persuaded him to try and get his son to buy the island, and deliver them from their bondage. This the Colonel consented to do, as he took an interest in the place, he having been, it is said, born there. Negotiations were opened up with Mr. Hume, who being in want of money at length consented to sell, although with considerable reluctance. The Colonel having obtained possession, now re-visited St. Kilda, and to the great joy of the natives abolished all irregular exactions, and gave instructions that a nominal rent only should be paid him, which he would send a man to collect twice a year. After the Colonel's death the island passed into the possession of his son, Sir John MacLeod, who continued the same generous treatment towards the islanders which his father had initiated. It is to this gentleman that the St. Kildans are indebted for the erection of their present comfortable little dwellings, the houses having been built by him purely from philanthropic motives, without any extra rent being charged. When Sir John was getting old, and he having no children, he decided to sell the island back to MacLeod of MacLeod, the father of the present Chief, and thus about 31 years ago the island passed again into the possession of the family whose original acquirement of it dates back for several centuries. Under the mild sway of the present generous landlord, the St. Kildans can look forward with confidence to a continuance of just and considerate treatment.

I was fortunate in getting a calm day for visiting Stack Lii, one of the most interesting bird stations in the whole St. Kildan group. This huge rock mass is upwards of 500 feet in height, and the top and sides are so crowded with Gannets sitting on their nests, and the rocks are so plastered with their droppings, that the whole upper part of the Stack appears perfectly white when viewed from a distance, whilst lower down long lines and streaks of white indicate additional nesting ledges. From the sea, even on near approach, the rock appears quite inaccessible, but the climb is not so difficult as it appears to be, as the ledges are much broader than they look. The landing is particularly interesting. The boat approaches a perpendicular wall of rock, which may be anything from twelve to twenty feet or more in height, according to the state of the tide, for the ascent of which no means are apparent. In a ledge above the rock wall, however, a small iron staple has been fixed, and the first thing to be done is to throw the noose of a rope over this. As the staple cannot be seen from the boat, the operation requires some nicety.

A successful throw having been effected, however, and the rope made taut, the first man to land walks up the perpendicular rock face, with his feet at right angles to the rock, hauling himself up hand over hand by the rope now fixed above him. When your turn comes to land you follow suit, but with the additional advantage of having a rope tied round your waist and held by the man above, who can thus render material assistance. It is possible for a person to be hauled up in this way to the ledge above as a dead weight, but the proper method of procedure is to walk up, as the natives do, with the feet at right angles to the rock, and a little confidence enables this to be done, especially with the assistance afforded by the second rope. The climb to the top of the Stack is a very interesting one. There are two rather awkward bits to surmount, but when these have been successfully negotiated, the rest of the climb presents no particular difficulty. On the way up you get amongst a crowd of Guillemots nesting on the ledge by which you ascend, and here I identified several of the Ringed form sitting on their eggs. Near the top of the ledge by which the ascent is made is a little rude shelter, the so-called "house," which the men used to occupy even for some days at a time when making raids upon the Gannets. The floor is now silted up with a large collection of Gannet bones, the remains of a former successful foray, which the men had been unable to remove. The shelter of the "house" was evidently appreciated by the Fulmars, for I found that five of these birds had taken possession, and were sitting each on its single egg, which rested on a layer of Gannet bones. The top of the Stack is made up of two extensive sloping faces, and the sight presented when these are reached is a wonderful one, the whole surface being thickly covered with Gannets sitting on their nests, which occupy every portion of available rock, so that it is impossible to walk in places without treading on the nests. The birds showed considerable reluctance to leave their nests, but none of them remained long enough to permit of being caught with the hand. The view from the top of the Stack is a very striking one, and the immense number of Gannets soaring in all directions around from the level of one's eye right down to the sea, furnished a most exhilarating spectacle. After leaving Stack Lii, we proceeded to Stack an Armin, where I anticipated landing without difficulty, as the sea was comparatively calm; but though the landing on this Stack presents no special difficulty when the wind is in the proper quarter, the north-west, it is only when the wind is in that quarter that this can be accomplished. On this occasion the wind was in the north-east, and when we arrived at the strait between Boreray and Stack an Armin, we encountered, to my surprise, a really heavy sea, and any attempt at landing on the Stack was entirely out of the question; it took us, indeed, all our time to steer the boat safely round the point of Boreray. Although Stack an Armin is both higher and more extensive than Stack Lii, the climb is said to be quite easy, and not nearly so interesting as that of Stack Lii, as on one side the rocks slope gradually all the way up. Gannets are very abundant, whitening the top and sides of the Stack, but they are not so numerous as on Stack Lii. There are, however, more Guillemots and Razor-bills than on the latter Stack, the Razor-bills being particularly abundant, and constituting a very extensive colony. The row round Boreray is a very interesting one, the cliffs on the west and north-west sides being particularly fine, towering up in pinnacled masses to a height of from 1,000 to 1,100 feet, the pinnacled tops being clothed with a bright yellow lichen. Gannets are very numerous, nesting on all available ledges of these cliffs. Before leaving Stack an Armin, it is interesting to recall here the tradition which renders it probable that it was on this spot that the last British specimen of the Great Auk was captured. I took the story down from the lips of the grandson of the man who assisted at the poor bird's destruction.* Norman McKinnon, who speaks English well, had often heard his grandfather (Lauchlan McKinnon) relate the particulars of the occurrence, and the account bears all the evidence of being substantially accurate. Norman's grandfather was on Stack an Armin, engaged with some other men in catching Gannets for the sake of their feathers, &c., living at the time in one of the little "houses," such as the men used to occupy on such occasions. As the young Gannets were then fledged, it would have been towards the end of August. When the men were desirous of getting away, continuous bad weather came on, which kept them prisoners on the Stack. One day they saw a very strange bird at the back of the "house," such as they had never seen before. It was described as being about the size of a year-old lamb, with a head like a Razor-bill and short wings, so that it could not fly. The men caught the bird, tied a rope to its leg, and kept it for two or three days. The extraordinary appearance of the bird impressed the men so much, that they thought it was a ghost, and looked upon it as the cause of the bad weather which they were experiencing. They therefore killed the poor bird, and threw it at the back of the house, covering it with stones. It has ever since gone by the name of the "Ghost bird." Norman's

*I was not aware until my return from St. Kilda that Mr. Henry Evans had published an account of this incident, derived from personal investigation on the spot (*vide* Harvie-Brown and Buckley's "Vertebrate Fauna of the Outer Hebrides"), but the result of an independent enquiry may not be devoid of interest.

grandfather was at that time a young unmarried man, probably (as the St. Kildans used to marry early) about 23 years of age, and he died in 1897 at the age, it is said, of 90. This would make the incident of the Great Auk happen about the year 1830. The date is, of course, only approximate, and if we allow of an over-estimation of five years in the old man's age at death, we should get the year 1835. Probably enough we might put the date of the occurrence somewhere between those two years. The bird has never been seen in St. Kilda since. I may add that Stack an Armin slopes gradually up from the sea on one side, and would have been a quite suitable place for a Great Auk to have taken refuge on under stress of bad weather. It is, of course, a historic fact that the Great Auk at one time bred in St. Kilda. Both Martin (3) and Macaulay (4) refer to it in unmistakable terms, and their information could only have been gathered on the spot. It is evident, however, that the bird must have discontinued its visits for many years, or at least have become a very great rarity before the date of the incident just related, as otherwise the natives would not have been so impressed with its arrival.

The day after my visit to Stack Lii, I was fortunate in being able to land on Levenish, as owing to the conflicting currents which meet around this rock, it is a difficult place to get a footing on, even in calm weather. On the side facing St. Kilda this Stack is quite perpendicular, but it slopes away gradually on the opposite side, and is therefore at that part quite easy to climb when a landing has once been effected. There are numerous broad ledges on the perpendicular face of the rock, which are tenanted by crowds of Guillemots, and several pairs of Great Black-backed Gulls nest on and below the grassy top: but what interested me most was the discovery which I made of a small colony of Fork-tailed Petrels nesting, which had not previously been known to the natives.

The isolated position of St. Kilda would lead one to anticipate that some modifications might be found in the resident fauna of the district, and this anticipation is realised. The Wren is a well known instance of this. It is not, however, so generally known that the mice also present distinct peculiarities as compared with the corresponding mainland forms. I am indebted to Mr. Newstead for calling my attention to the work that has been done on this subject. Both our common mice, *Mus sylvaticus* (field mouse) and *Mus musculus* (house mouse) are represented by peculiar forms. The first specimen of the peculiar field mouse of the island, which has received the name of *Mus hirtensis*, was obtained and described by Mr. Steel Elliott (5) in 1895; and in 1899 Mr. Barrett Hamilton (6) published a paper treating exhaustively of this species, and of the St. Kildan form of the house mouse, which was described as a new species under the name *Mus muralis*. Reference may be made to the above communications for a full account of these interesting new species or sub-species; but I may here briefly state that the St. Kildan field mouse (*Mus hirtensis*) is larger than the ordinary form of *M. sylvaticus*, its back is more inclined to grey, and the underside has a greater amount of buff or yellowish brown colouration, and even in some cases a slight rufous shade; whilst *M. muralis* is also a larger and more robust species than the common house mouse, the colour of its back resembles more a dark specimen of typical *M. sylvaticus*, while the colour of the under surface is buff, separated by a well-marked line of demarcation from the upper surface. There are also differences in the skulls.

I now propose to give an account of all the birds which are resident in the St. Kildan group, or which visit those islands for the purpose of breeding. The time is not yet ripe for giving a complete account of the entire avifauna of St. Kilda, for there can be no doubt that many species occur there on migration, or are occasional visitants, but the presence of which has been overlooked owing to the lack of observers. Dixon (7), who visited the island in 1884, published a complete list of all the birds, which had up till then been recorded, though some of these were, I think, admitted to his lists on insufficient evidence. Since then a few additions have been made, the most interesting of which was an example of the sub-Alpine warbler (*Sylvia subalpina*) which was shot by Mr. J. Steel Elliott (5) in June, 1894. In Mr. Elliott's list two other birds are given on the authority of Mr. McKenzie, which are not down in Dixon's list, viz., the common Swift and the House Martin. The former of these two birds was also seen by my friend Mr. Wheat, during his visit to St. Kilda in 1899; whilst as regards the latter, I myself saw an example flying round the cliffs on the south side of the main island on the afternoon of June 8th. The Brent Goose was also once observed by Heathcote (1). I am able to add another bird, which has not, so far as I know, been previously recorded, namely, the White Wagtail (*Motacilla alba*). Two of these birds in full breeding plumage, frequented the little patches of cultivated ground about the village during the week previous to my departure (June 18th to 25th), and as I saw them several times, and was frequently quite close to them I feel confident as to their identification. They might have been nesting, but I failed to obtain any evidence of it. I may also add the Mallard (*Anas boscas*), which visits St. Kilda in the autumn, on the strength of a skin forwarded to me since

I left the island, the bird having been shot last September. There are certain birds also which have been observed on St. Kilda, and which may possibly breed there, though the nests have never yet been discovered. One of these is the Dunlin (*Tringa alpina*). On June 14th I saw four of these birds in full breeding plumage, running about the boulders which crown the beach at Village Bay, and on a patch of marshy ground adjoining. They were very tame, and allowed me to approach within three or four yards without flying off. It is quite possible that this bird may eventually be found breeding on some of the high ground in the island, though I did not myself meet with it in that situation. The Whimbrel (*Numenius phæopus*) is another case in point. It is not uncommon round the coasts, where I frequently saw it, and I had two recently shot birds brought to me. I was assured by the natives that it was frequently seen on the high ground during the summer; but though I explored every possible nesting site for it on several occasions, I failed to discover the least evidence of its breeding. It is quite possible, however, that it may do so at times. As the breeding of the common Snipe in the island has only quite recently been definitely established, it is reasonable to suppose that the list of breeding species will be somewhat extended as the group becomes better worked. The Meadow Pipit (*Anthus pratensis*) may also be mentioned in this connection. I saw a bird on the top of Mullach Mor one afternoon, which I am confident was of this species, but I failed to discover any nest. It probably breeds, though its nest has apparently never been taken. On the other hand, some birds are given as breeding species by Dixon and others, the nesting of which is doubtful. As to *Larus fuscus*, which is said by Dixon (7) to breed plentifully, I failed to discover any evidence; although I was on the constant look out for it, I never once saw it. Nor could I ascertain that the natives were acquainted with the bird, which they assuredly would be if it were there in any numbers. It seems to me very doubtful if it breeds on the islands. Similarly as regards *Larus canus*, given as a breeding species by Sir W. Milner (8). I never saw a trace of this bird, and am confident that it does not breed there. The Cormorant also (*Phalacrocorax carbo*) I never saw, and could obtain no evidence of its breeding. In these respects my experience coincides with that of Mr. Steel Elliott (5).

The subjoined list comprises all the birds known with certainty to breed in St. Kilda, though doubtless the list is capable of extension. All those here included I can personally vouch for.

List of Birds breeding in St. Kilda either as Residents or Summer Visitants.

Corvus corax (Raven).

There are five or six pairs of these birds in the St. Kildan group, one on the main island, one on the Dun, two on Boreray, and one at least on Soay. These nests are all known, but the eggs are seldom taken. A clutch of six eggs was taken by Neil Ferguson the last week in March of this year (1902), they were considerably incubated, and three of them were broken in blowing; the remaining three, which I saw, were of the usual crow type, but small for Ravens' eggs. Fully fledged young birds were seen by Neil Ferguson in the month of May, both on the Dun and on Soay, and another lot on Boreray in June; so that three nests at any rate hatched off successfully this year. The birds are resident all the year round, and come about the houses a good deal in the winter.

Corvus cornix (Hooded Crow).

Very abundant and tame. Their hoarse note is one of the first bird sounds heard in the morning, and the birds are in evidence wherever one goes on the islands. They come close up to the cottage doors in search of offal, and, indeed, act as efficient scavengers. I have frequently stood within a few yards of them when thus engaged, without them flying off. Considering the abundance of the birds the nests are not often taken. Four clutches of eggs, each containing four, were taken this year (1902). Resident.

Sturnus vulgaris (Starling).

Plentiful, breeding in the stone walls and cleits, generally low down and even on the ground amongst the bottom stones of the wall. I saw a nest in the latter situation. In the third week in June the old birds were busy feeding their young, which, from the loudness of the cries proceeding from the walls of the cleits, appeared to be well advanced. Resident.

Saxicola œnanthe (Wheatear).

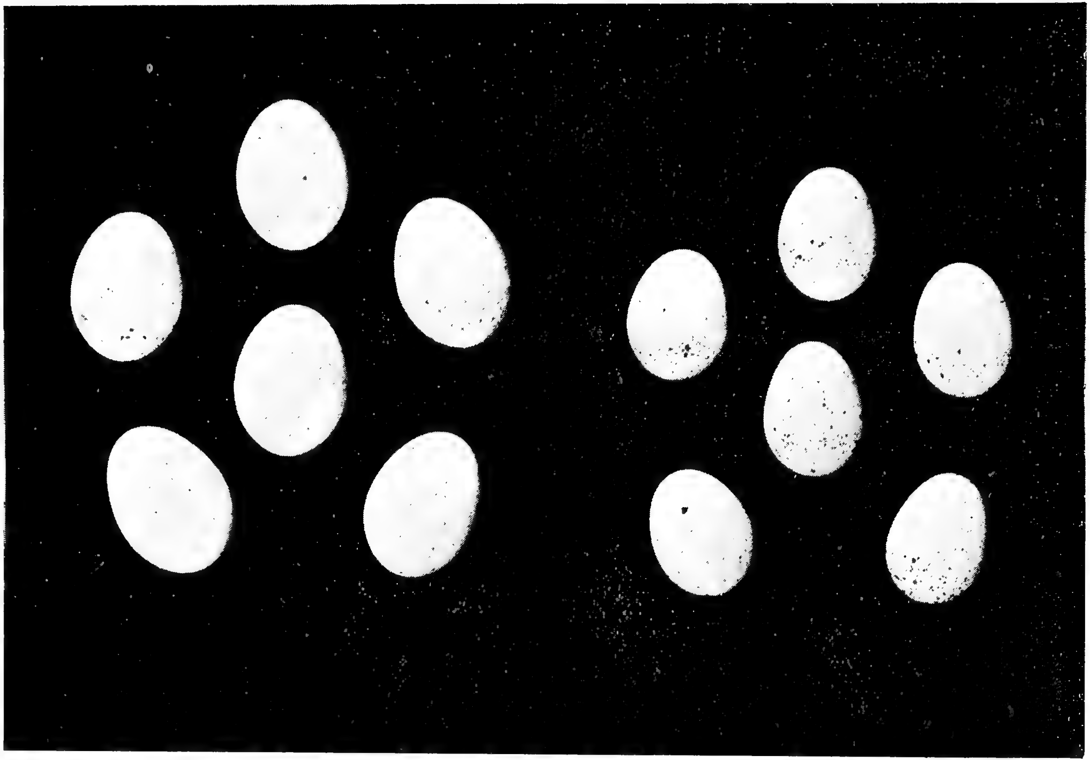
Pretty plentiful all over the island, breeding amongst piles of boulders, and in the stone walls of the cleits, etc.

Troglodytes parvulus hirtensis (St. Kildan Wren).

To Dixon belongs the credit of being the first to recognize that the Wren inhabiting St. Kilda differed in some respects from the common wren of our islands; and these differences led Seebohm (9), to whom the specimens obtained were submitted, to describe the bird as a distinct species under the name of *Troglodytes hirtensis.* Dresser (10), however, considers that the differences are not sufficiently great to justify the elevation of the bird to specific rank, especially when it is compared with examples of Wrens from other parts of Europe. The latter view is, no doubt, correct, but the peculiarities of the St. Kildan bird are, nevertheless, sufficiently pronounced to constitute it a distinct local race or sub-species, and as such the name which Seebohm gave it, may well, in my opinion, be retained as the third term of a trinomial series, as, indeed, Seebohm himself suggested as an alternative to giving the bird specific rank. The St. Kildan Wren is about the same size as the common wren of our islands, but the bill and feet are slightly larger and stouter. The general tint of the plumage of the St. Kildan bird is distinctly lighter than that of the common form, and the barring of the back from the neck downwards is distinctly more pronounced; the lighter colour of the underparts of the St. Kildan bird is also very manifest, as well as the more profuse barring of the abdomen, flanks, and under-tail coverts. The above characters are well shown in a specimen which I obtained on the island, which was skinned and preserved on the spot, and the pale colour cannot, therefore, be due to preservation in spirits, as Dresser (10) appears to suggest, since my specimen never came into contact with spirit at all. The light colour certainly renders the bird less conspicuous amongst the grey rocks, which it frequents, than the common form of *T. parvulus* would be, and it has doubtless been modified in this direction by a process of selection.

The nest of the St. Kildan wren closely resembles that of the common British type, but the materials of which it is composed are coarser than is usual in the case of the latter bird, and it is not quite so neatly constructed. A favourite situation for the nest is amongst the stones of the cleits, but it breeds amongst the rocks, and I carefully examined two which were placed in the latter situation, one on Boreray, and the other on Soay. The position occupied in both these cases was strikingly similar, and the one nest was almost a counterpart of the other. The nest was placed well beneath a large overhanging tuft of a coarse wiry grass (Aira flexuosa) which in the one case overhung the top of a peaty bank amongst the cliffs, and in the other grew out of a crevice in the naked rock. The nest was placed right in amongst the withered stems of the previous year's growth of grass, and was exceedingly well concealed. To add to the deception the exterior of the nest itself was composed of dead stems of the same withered grass amongst which it was placed, the whole being woven together in such a way that it was difficult in some places to say where the nest ended and the dead grass, amidst which it was placed, began. Inside this layer of dead grass stems was a neatly constructed nest, composed almost entirely of dry moss and feathers, and lined throughout with feathers. The usual clutch of eggs is six, and I could not hear of any larger number being ever found. The eggs do not differ in colour and appearance from those of the mainland form, being pure white in ground colour, generally more or less spotted with red, but at times without markings; they are, however, considerably larger in size. The comparative difference in size between these eggs and those of the mainland wren, is well shown in a photograph given by Mr. Kearton (2), as well as in the accompanying plate taken from my own specimens. Three of my specimens from St. Kilda measure respectively, ·72in. by ·55in., ·74in. by ·56in. and ·78in. by ·57in., as compared with a measurement of ·66in. by ·50in. for English wren's eggs. The habits of the St. Kildan bird do not appear to differ from those of its congener, but its note is louder, clearer and more prolonged. The nesting season seems to be somewhat irregular, but the eggs appear to be usually laid towards the end of May, or in some years the beginning of June, though in mild seasons they are earlier than this. In the two nests above referred to, which I have every reason to believe were first layings, the one on Boreray contained two fresh eggs on June 5th, so that the bird had then only just begun to lay; whilst the one which I found on Soay on June 9th, contained six eggs which were perfectly fresh, and the bird had just commenced to sit. Last season, however, was a cold and backward one, and, doubtless, the birds were later than usual.

As to the origin of this local race of wrens one can, of course, only conjecture, but I should be disposed to think that they are the modified descendants of the birds which



Clutch of St. Kildan Wren's Eggs. Clutch of English Wren's Eggs.

(From a Photograph.)

inhabited the district at the time when St. Kilda was connected with the mainland of Scotland, as there is good reason to believe it once was.

Anthus obscurus (Rock Pipit).

Plentiful all round the rocky coasts of the islands, where it breeds. I frequently saw it, and even came across it on the isolated rock Levinish, where it was evidently breeding. Resident all the year.

Passer montanus (Tree Sparrow).

Fairly plentiful, breeding in the stone walls and cleits in the neighbourhood of the Village. A thick high wall formed of loose uncemented stones running down from the Village to the bay, is a favourite place for them. On June 18th I discovered a nest containing young three or four days old, and two days later (20th) I found two nests with five fresh eggs in each. These were in all probability first layings, as the natives do not trouble to take the nests of any small birds except those of the wren, and I saw no young birds about. The season, moreover, was a very cold and backward one.

Linota flavirostris (Twite).

Fairly plentiful. I frequently saw the bird, and think there can be no doubt that it breeds, though I never saw any nest. On June 8th I watched for some time two male birds courting a female about the stone walls on the hill side, above the Village.

Falco peregrinus (The Peregrine Falcon).

This is the only member of the Hawk family resident in St. Kilda. There are three or four pairs on the islands, one or two on Dun, one on Soay, and one on the main island. Four clutches of eggs were taken by the natives this year, one of which I saw; one of the clutches might have been a second laying. On June 25th, when part way down a cliff on the south side of the island, one of these birds flew over my head and I heard its cry two or three times.

Phalacrocorax graculus (Shag).

Resident, and fairly plentiful, breeding both on the main island and on Soay. There is an interesting little colony of these birds nesting amongst boulders at the base of the cliffs on the N.W. side of the main island, which, at the time of my visit, consisted of about sixteen pairs. There has at this spot been an enormous fall of rock from the roof of a large cave, which has not merely filled up the floor of the cave, but the boulders thus formed, many of them of very large size, extend for some distance beyond its mouth. It is beneath these large boulders and slabs of rock that the Shags breed, the nest in every case being placed well under a large slab so as to be completely roofed over. At the date of my visit, on June 23rd, most of the occupied nests contained young in different stages of growth, but two of them contained fresh eggs in clutches of two and three respectively. As the colony had been raided by the natives earlier in the year several of the nests were empty. Another similar nesting site beneath large boulders of rock occurs somewhat further to the west, opposite Miana Stack, but here the colony is much smaller, and I only saw three or four nests.

Sula bassana (Gannet).

This bird breeds in enormous numbers in one locality only of the group, viz., Stack Lii and Stack an Armin, and the adjoining cliffs on the west and north sides of Boreray. It is not resident, leaving the rocks after the young have flown, and is very rarely seen about in the winter. The largest concentration of these birds relative to area is on Stack Lii, the entire top of which is perfectly white with them, as well as the encircling ledges; but Stack an Armin is not greatly inferior to its neighbour in this respect, although the birds are definitely less numerous there. On the cliffs of Boreray there are as many birds as on the Stacks, but these being spread over so much greater an area, the effect is not so striking. A few birds are seen about the Stacks where they breed early in March, and by the end of that month the rocks are fully tenanted. In April they set about making and repairing their nests. They begin to lay sparingly in favourable seasons at the end of April, but the eggs are not obtained in any numbers before the first or second week in May. Fully a fortnight will elapse from the time of the first birds laying before eggs are found in all the nests. On the occasion of my visit, on June 10th, the sloping faces on the top of Stack Lii were crammed with nests as thick as they could be placed, every available spot between the projecting angles and slabs of rock being thus occupied. Almost every nest contained a single egg, the great majority of which was stained a deep brown colour, and these were all, so far as they were tested, considerably incubated, the embryo being formed, but not of large size. There was, however, a fair sprinkling of perfectly fresh, clean eggs. I saw four nests containing two eggs each; in one of these both eggs were much stained and badly incubated; but in the other three, whilst one egg was in this condition, the other was perfectly fresh and clean, so that a considerable interval must have elapsed between the layings, which were in all probability performed by different birds. As the top of this Stack had been cleared of eggs by the natives on May 14th, the great majority of the eggs in the nests must have been second layings. The eggs are taken partly for food, and partly for sale to tourists and dealers. The Gannets were formerly a source of considerable profit to the natives, and they are still prized, though to a less extent. They were, and still are, captured on their arrival in the spring, both for food and for the sake of the feathers; but the great raid on them used to be early in September, when the young ones were fledged, but just before they were ready to fly. The young were eaten, but they were especially valued for their oil and their feathers. They were killed in large numbers, and being brought over in large boatloads, were skinned, and the skin, with the adhering fat, was boiled, the oil rising to the surface and being skimmed off; the fat inside the body of the bird was melted down by itself without boiling. The men used to get 1s. a pint for the oil, but now they can only get 4½d. offered for it, so that it is not worth their while to go through the labour involved to get it. Hence during the past few years the autumn raid upon the young gannets has been discontinued. The adult birds are, however, still captured on their arrival in the spring, generally about the middle of April, at which time alone are they considered fit for eating. They are captured at night, and the darker the night the better, whilst the association of a dark night and pouring rain furnish the most favourable conditions. Those who have climbed Stack Lii will appreciate the skill and hardihood of the natives in performing the task in the dark, especially if the rocks are wet with rain. There is always a sentinel awake for every group of Gannets, and the success or failure of the expedition hangs entirely on the capture of the sentinel. The men creep up very quietly to the spot, and take the opportunity of seizing the sentinel when he is off his guard, picking at his breast or preening his feathers; he is seized by the bill and his neck broken by throwing his head back. If the sentinel is disposed of all the other sleeping Gannets, which are lying with their heads under their wings, can be seized and killed without difficulty, provided no noise is made. As many as two or three score may thus often be taken one after the other. Frequently, however, the sentinel sees the approaching danger, gives the alarm, and the birds are all off at once. This happens more particularly upon light nights. I endeavoured to form some sort of estimate as to the number of gannets resident in St. Kilda during the summer by ascertaining the number of eggs taken. On May 14th there were taken from the top of Stack Lii (from the summit only) 1,400 fresh eggs; the great majority of the birds had then laid, but some nests were still unoccupied. Perhaps, then, 1,500 nests might represent the number on the sloping faces on the top of this stack only. But the men say that on the whole of the rest of this stack there are more nests than on the summit, and if this be so, the total number of nests on Stack Lii may perhaps be put at 3,500 to 4,000. On Stack an Armin, though the birds are very numerous, they are appreciably less so than on Stack Lii, and the number of nests may perhaps be put at about 3,000. On the cliffs of Boreray the natives consider that there are more nests than on the two stacks put together, and the number may therefore be approximately reckoned at about 8,000. Doubling the number of nests to get the number of birds, and allowing for a fair sprinkling of non-breeding birds, of which the natives say there are a good many, we get a total of some 30,000 birds. This estimate is much less than that given by some writers, and it, of course, does not pretend to be more than a rough calculation. It probably errs on the side of deficiency, but at the same time it has to be borne in mind that 1,000 birds of the size of a Gannet make a big show, and a mere cursory view of their numbers would probably lead to an overestimation.

Somateria mollissima (Eider Duck).

This is the only species of duck which breeds at St. Kilda. It nests both on the main island and on Dun, and possibly on the other islands also. It is by no means plentiful, and can scarcely, I fear, hold its own much longer on the main island, as the eggs, and even the sitting bird, are taken by the natives on every possible opportunity. I saw two drakes and a duck on June 9th, when rowing round the south side of the island, and I was shown a clutch of five eggs which had been taken on Dun previous to my visit. On June 21st, when on the top of Mullach Mor, a boy who was on the hill at the same time, brought me in triumph a duck which he had just caught on her nest. I went with him to the nest, which contained four eggs, all chipped for hatching, and the young birds within chirping vigorously. With some difficulty, and with the aid of a pecuniary solatium, I got the lad to relinquish his prize, and put the bird back on her nest, and I hope she brought her young off in safety. It is no wonder that the bird holds its own with difficulty.

Hæmatopus ostralegus (Oyster Catcher).

Not numerous, but several pairs breed round the coasts, where the rocks are low enough for the purpose. On June 16th I found a nest containing four eggs amongst the rocks at the bottom of the Glen.

Gallinago cœlestis (Common Snipe).

The first snipe's eggs ever known to have been taken on St. Kilda, were obtained by a native in the summer of 1900, and sent by Alec Ferguson to my friend Mr. Wheat (who visited the island in 1899) for identification, as none of the natives knew what they were. Two nests were discovered whilst I was on the island. The first of these with four fresh eggs was brought to me on the evening of June 20th by a woman who was working on the hill, and who found the nest by accidentally flushing the bird from it. The next morning I went with the woman to the spot and got her to replace the nest in the exact position in which she found it. It was a typical snipe's nest placed in the centre of a tuft of coarse grass high up on the side of one of the hills directly facing Village bay. It was about 150 yards from a spot on the hillside where I had flushed a snipe from a little rill about a fortnight previously. Three days later the same woman found another nest with three eggs on the opposite side of the island, on a hill facing down into the Glen. This time the nest was left *in situ*, and on visiting it the following afternoon I found that it still contained only three eggs, and there was no sign of the bird. On going to the spot again, however, on the following morning, June 25th, the bird was on the nest, and I watched her for some little time from a distance of only a few feet before she flew off, so that the identification was complete. The nest was then full clutched. The fact of the snipe breeding in St. Kilda is, therefore, definitely established. It is remarkable that fresh eggs should have been obtained so late in the season, since there is every probability that they were first layings; at any rate it is quite certain that none had been taken by the natives that season, previous to these.

Larus argentatus (Herring Gull).

This is "the common gull" of the natives. Whilst pretty plentiful it cannot be exactly called abundant. It breeds on all the islands, and on June 9th, on Soay, I saw a clutch of three eggs chipped for hatching. It comes to the neighbourhood of the Village and assists the Hooded Crows in acting the part of scavengers, but it is less bold than the latter birds.

Larus marinus (Great Black-backed Gull).

Resident and fairly plentiful, and would be much more so than it is, were not its eggs taken and its young destroyed by the natives on every possible opportunity. As in other places, it shows a special preference for nesting on isolated stacks and narrow projecting headlands, but I found one nest, identifying the bird perfectly, on the hillside on Soay, near the "Altar," in such a situation as *Larus fuscus* might choose. On June 6th I found on the top of Soay Stack a single nest containing three young just hatched; this stack had not been landed on previously that year, so that the pair of birds had bred undisturbed. On June 11th I found four pair of birds breeding on Levenish. One of the nests contained two young birds, four or five days old, and another three eggs just ready for hatching. Two other nests contained two and three eggs apiece, nearly fresh; these latter were doubtless second layings, as the rock had been visited before by the natives, on May 19th, and they would have taken every egg they saw. This bird and *L. argentatus* are great robbers of Fulmars' eggs, if these are left exposed by the parent bird quitting the nest, and are disliked by the natives accordingly.

Rissa tridactyla (Kittiwake).

Very plentiful, breeding in numerous scattered colonies round the coasts of all the islands, including Boreray, especially on the south side of Dun, and on the west side of the main island, and on the cliffs and stacks in the neighbourhood of Soay Sound. Although there is no single colony of very large dimensions, many of them are nevertheless of considerable size, and in the aggregate their numbers must be very considerable. They are fond of portions of cliff from which large masses of rock have become detached, leaving irregularities of surface which serve as supports for their nests. This bird is not resident, but leaves the rocks in the winter.

Alca torda (Razor-bill).

Very numerous, although much less so than the Guillemot. The largest colony on the main island is amongst the broken rock masses on a little promontory in the neighbourhood of Miana Stack. It breeds plentifully on Soay, and more particularly so on Dun, especially towards the point, where the huge chaos of rocks and boulders afford it a safe and congenial retreat. The largest colony of all, however, is on Stack an Armin, which I was prevented landing on by contrary winds. Like the Guillemot, if the first egg is taken, they will lay a second and even a third time. They come to the rocks rather later than the Guillemots, but they begin to lay about the same time, and the young are hatched, and leave about the same time as those of the Guillemot. They are never seen about in the winter.

Uria troile (Common Guillemot and Ringed Guillemot).

As might be supposed, these birds are exceedingly abundant, breeding all round the coasts of all the islands, and on every stack, wherever suitable ledges exist for the deposit of their eggs. Vast numbers of eggs are taken every year for food and for sale to tourists and dealers, and owing to the development of the latter traffic many more eggs are taken now than formerly. It was calculated that last season about 300 eggs were obtained for each of the sixteen houses, giving a total of 4,800; but last season, owing to the bad weather, and the men not being able to visit Stack an Armin and other places, there were not so many eggs taken as usual. In favourable years it is said that fully 6,000 eggs are taken. These figures, of course, include second layings. It might be thought that this wholesale depletion would clear out the whole Guillemot population, but from my personal observations, and from information supplied me by the natives, I should say that fully one-half of the St. Kildan Guillemots breed undisturbed; in other words, that there are quite as many inaccessible Guillemot ledges as there are accessible ones. I was able on several occasions to get right in amongst a crowd of these birds on their nesting ledges, and to pick up the eggs myself. I was, therefore, enabled perfectly to identify some eggs from the Bridled or Ringed form of Guillemot, which was always to be seen on the ledges in company with the common form. I noticed that the Ringed Guillemot was the less bulky bird of the two; thus, two common Guillemots weighed $2\frac{1}{2}$lbs. each, whilst two birds of the Ringed type weighed respectively 2lbs. and 2lbs. 2oz.

These birds are not seen about at all during the winter until about the last week in February, when they begin to make their appearance in the sea, but they are not seen on the rocks until the beginning of March. When they first arrive they come in the early morning, and stay on the rocks till about midday, when they go off to sea and remain at sea until the following morning; they will do that for three days, and then stay away at sea for another three days without coming to the rocks at all; then they will come back again in the early morning for another three days, going off at midday as usual. If the weather is bad they will stay out at sea for six days, instead of three (not, it is said, four or five days), and if the weather is fine they may stay six days on the rocks, that is, in the morning only. As the spring draws on they spend a longer time on the rocks. They act in this way throughout March and April. In March it will be daylight before they come to the rocks, but in April they come in the early morning before it is quite light. In the latter month they are caught by the natives in an ingenious manner. This method, which is of ancient date, is recorded by the older writers, sometimes with pretty fanciful additions, but it is interesting to learn that it is still practised, and to have an account of it from the lips of a native who had himself taken part in it. The men leave their houses at midnight, taking lanterns with them, and station themselves on the rocky ledges which the Guillemots frequent, with a rope tied round their waists and fastened to a stone above as a precaution in case they fall asleep (a contingency which actually at times occurs) and wait there till the morning. The fowler wraps himself up in a white sheet and puts a white cap on his head so as to make himself assimilate as much as possible to the rock, white with the droppings of the bird, on which he is fixed. When dawn is just breaking the birds come in from the sea, and settle on the fowler, mistaking him for a portion of rock. The first bird caught is killed by breaking its neck, and then the fowler puts the bill of the bird in his mouth, keeping the white breast out, so as to add to the deception; sometimes the man will tie a string round his waist and hang two or three birds to it with their breasts out, in similar fashion. The fun is fast and furious whilst it lasts, as the birds often come in so rapidly that the fowler cannot kill them quickly enough. The birds keep coming on in this way for about half an hour, but as soon as it gets light enough to distinguish the man from the rock, the arriving birds swerve off to one side, and no more can be obtained. Some 500 birds may in this way be taken in the course of a single night. The same ledge is only visited once a year, but different ledges are taken in succession. The men do not go out for this purpose on more than two or three occasions in one season. At this time, and this only, are they considered to be good eating, and they are caught for that purpose; the feathers, however are collected and sold. Early in May the birds come to the rocks altogether staying on them both by day and night. They begin to lay about May 15th or 16th, though they do not all lay at that time; May 18th, as nearly as weather permits, is the day chosen by the men for making a first raid after the eggs. Eighteen days after taking the first eggs, the men go for a second lot, as most of the birds have laid again by that time. Nearly as many eggs are obtained the second time as the first. Thus from one ledge on May 23rd 60 eggs were taken, and the same ledge on June 21st furnished 53 more. Some of the birds will even lay a third time if the second eggs be taken, but the number that do this is never more than half, and the eggs are distinctly smaller, so that they are seldom considered worth going after. When the birds have been undisturbed they are mostly hatched out about June 21st (some earlier) and the young ones are full fledged about the end of July. Old birds and young together will be seen swimming about all through August, but by the beginning of September they have nearly all taken their departure, and none are seen again until the end of the following February.

Uria grylle (Black Guillemot).

Resident, but by no means plentiful. The only place where I saw it was in the Dun passage, amongst the rocks in the neighbourhood of which it breeds; I saw a clutch of eggs taken from this locality, previous to my visit.

Fratercula arctica (Puffin).

It is difficult, without seeming exaggeration, to describe the immense multitudes of these birds which make St. Kilda their summer residence. Plentiful as they are on the main island, it is only when one visits the subsidiary islands that the full wealth of Puffin life becomes manifest. They occur in countless thousands on Dun, but on Boreray and Soay the vast hordes of these birds baffle description, and of these two islands the latter appears to be the most densely populated. They simply swarm everywhere, breeding indifferently on the grassy hillsides which are riddled with their innumerable burrows, and under boulders and masses of rock wherever these occur. They scuttle out of their burrows at every step one takes. They dot the grassy slopes in multitudes, and every little coign of vantage such as is afforded by a projecting rock, is thickly covered with them. They rise in the air with a loud whirling noise of wings, in thousands at a time, and fly past one in an apparently never ending stream. Abundant as these birds always were, there seems no doubt that of late years they have considerably increased in numbers owing to the fact that they are no longer secured for the sake of their feathers. Formerly immense numbers were killed for this purpose all through the summer, and the discontinuance of this practice has caused the birds to multiply to such an inordinate extent, that they are doing serious damage to the pasturage by riddling the hillsides with their burrows. A good many of them are, however, still snared for food, especially when they first come, and the eggs are also collected both for food and for sale. The puffins arrive with great regularity about the middle of April; at first, like the Guillemots, they only stay for three days and then go to sea again for another three days, but they gradually stay later. Though they arrive later than the Guillemots, they begin to lay earlier, and by the end of the first week in May a large number of birds have laid. On June 10th I found that they were just beginning to hatch out. They begin to leave about the middle of August, and by the end of that month nearly all the birds have disappeared, and they are not seen again until the following April.

Procellaria pelagica (The Storm-Petrel).

Plentiful on Soay, but it appears to be scarce on the other islands; though it probably breeds in other localities, the eggs have not, so far as I know, been taken elsewhere than on Soay. On the occasion of my visit to the latter island I was too early for this bird, and I was unable to land there later owing to the stormy weather. I have, however, seen eggs which were taken there subsequent to my visit, on ground which I had traversed.

Oceanodroma leucorrhoa (Leach's Fork-tailed Petrel).

St. Kilda is the great head-quarters of this bird in the British islands, and it is still plentiful there in spite of the serious inroads made upon it by the natives in order to supply the demands of dealers and tourists. I calculated that between 300 and 400 eggs were taken by the natives for this purpose last season. It is most abundant on Boreray, but it also breeds plentifully on Soay, whilst it is fairly frequent on Dun, though much less plentiful there than formerly owing to the manner in which it has been harried. It also breeds sparingly on the main island, and, as before mentioned, I discovered a small colony breeding on Levenish. It especially frequents

from the roof to the floor. This cavity was rather larger than some others measured. The nest usually measured from $4\frac{1}{4}$ to 5 inches across. I never saw any excavated material at the mouth of the burrows. Not unfrequently some fragments of dry grass, exhaling the petrel odour, were found near the mouth of the burrow, which were evidently portions of nesting material dropped by the bird near the entrance. When this was observed the burrow was always found to be tenanted. Dixon (7) long ago made the same observation. That the same burrow is frequently occupied in successive years is proved by my finding in one of the nests a fully developed but dried up embryo of a previous year, with fragments of shell still adhering, which from some cause had been unable to hatch out. The majority of the eggs taken on Boreray on June 5th were fresh, but some few were distinctly incubated, whilst I took a perfectly fresh egg on Dun on June 12th; so that it would appear that the laying season is somewhat extended. The natives are unanimous in stating that when the egg is taken the bird does not lay again that season. When the burrows were opened out the birds always retreated to the farthest corner of the nesting cavity, so as to be as much in the dark as possible, and when the nesting cavity had two exits, which it often had, the bird usually retreated along the one which had not been opened out, but in no case did it spontaneously fly off. When the birds were taken in the hand some of them ejected a little oil from their mouths, but the majority did not do this. When placed on the hillside with their heads facing up the hill, the birds invariably turned round so as to face down hill, and then after a few steps downwards rose on the wing without difficulty. After a few moments of fluttering hesitation, they flew off with a rapid zig-zag flight, with strong beats of the wing, and were soon lost to view out to sea, or behind the cliffs. One of them in its flight violently collided with a puffin and fell to the ground as if dead, but after about a minute it recovered itself and rose again on the wing. They were very silent. In the case of four birds taken on the egg, dissection showed them all to be males. These birds are said to arrive in April and to leave in September. The plumage of the young bird almost exactly resembles that of the adult.

Puffinus anglorum (Manx Shearwater).

This bird appears to be still plentiful, but less so than formerly, owing, the natives say, to its having been driven out by the increase of the Puffin. It breeds both on the main island and all the subsidiary islands, but is most abundant on Soay. Its burrows are generally deeper than those of the Puffin, and it is difficult to get at. There is an interesting colony of these birds on the main island, where they nest under enormous boulders, which have at some distant period been detached from the cliffs above, and now strew the hillside in endless confusion. Some of these boulders are of immense size, and there are formed underneath them regular caverns large enough for a man to crawl along; and it is in burrows leading out of the damp, gloomy recesses thus formed that the Shearwaters lay. An egg which I obtained in this situation, on June 18th, was very highly incubated—almost ready for hatching, in fact. The sitting bird proved, on dissection, to be a male. Another bird, also a male, captured in another burrow, but which was not on an egg, had the proventriculus distended with a soft greenish pulpy substance, having much the appearance and consistence of boiled spinach, only of a brighter green; whereas the stomach of the sitting bird was empty. The natives say that the Manx Shearwater comes in March and leaves in August.

Fulmarus glacialis (Fulmar).

This bird, as is well known, nests in enormous numbers in every part of St. Kilda, and constitutes a valuable source of profit to the natives. Whilst breeding in great numbers on the main island, and plentifully enough on Dun and Boreray, and many of the stacks, one must go to Soay to realise the full extent of Fulmar life. I have already referred to the immense multitudes of these birds which breed in that island, especially along the magnificent rampart of cliffs which constitute its northern face, and I have no hesitation in expressing my opinion that there are more Fulmars in the island of Soay than in the whole of the rest of the St. Kildan group put together. The bird appeared to nest indifferently both on grassy slopes and ledges, amidst and below the cliffs, and upon ledges and between angles of bare rock, especially where the cliff face was a good deal broken up into large rock masses and platforms, wherever, indeed, there was a sufficient extent of flat surface upon which to form the scanty nest. This nest consisted of a shallow saucer-like depression turned in the peaty soil, or a still shallower depression amongst the detritus of the rocks; this depression was in many cases completely unlined, the egg resting on the bare peaty soil, but it was more usual to find the cavity containing a little dry herbage, frequently small dry tufts of sea-thrift (*Armeria*), and also some small flat fragments of stone. When the nest was placed amidst bare rocks, it was very usual to find the shallow cavity lined with these little flat pieces of stone, often mere flakes, which had obviously been collected by the bird; but when the nesting cavity was formed on the herbage-covered ledges and grassy

Fulmar Petrel on Nest. Boreray.
(From a Photograph by Mr. R. Newstead. By kind permission.)

slopes, the tendency to line the cavity with these flakes of stone was not so pronounced, although still apparent; in fact, I saw one or two nests in the latter situation in which the hollow in the bare peaty soil (for the bird seems to scrape away the surrounding herbage before forming its nesting cavity) was lined with a complete pavement of small flat flakes of stone. This tendency, indeed, to line the nesting cavity with small fragments of stone seems to be the most characteristic thing about the Fulmar's nest. I observed the same thing when visiting the nesting haunts of this bird in Shetland. The Fulmar may be said to be resident in St. Kilda, for it is seen about the rocks all the year round, with the exception of about a month after the young have flown, that is, from about the end of August till the end of September, during which time not a single bird is observed on the cliffs. They begin to return about the beginning of October, and remain all the winter. The nesting season begins towards the end of the second week in May, and, as a rule, about the 12th of that month about half the birds will have laid. At that time the Gulls are very much on the look-out for the eggs, and if the birds are disturbed by persons going down the cliffs, the Gulls will at once sweep in and seize the eggs, and considerable numbers are often destroyed in this way. If the egg is taken, the bird will not, it is said, lay again that season. In a wet season a number of the eggs get addled. By June 21st, the earliest of the young Fulmars are being hatched, and by August 12th they are fully fledged, though not as a rule able to fly for about another week. Both sexes incubate. Two out of five birds snared on the nest were males, and the other three females. I had many opportunities of observing the well-known habit the sitting bird has of ejecting oil from its mouth on the approach of an intruder. Although all the birds did not make use of this method of defence, the majority of them certainly did so. The oil, which was a thin, foul-smelling amber-coloured liquid, generally containing green particles floating in it, was usually ejected for a distance of about three feet without, in the first place, much effort, but when, as not unfrequently happened, a second discharge was made, this was always preceded by visible efforts at eructation on the part of the bird: I have even known one bird make a third discharge, when closely approached. On two occasions I noted that the vomited matter contained a narrow fresh green frond of the common alga, *Enteromorpha compressa*, and once I also observed the carapace of a crustacean, apparently a large prawn. Although the oil was often ejected directly at an approaching intruder when perhaps one or two yards off, it was also often discharged in a very random manner long before one came within striking distance, and when descending a cliff I have seen Fulmars parting with their oil when I have been as much as fifteen or twenty feet off, and ejecting it into the air quite away from the direction by which I was approaching. The young ones will eject more oil than the old ones; they will even spit it out when only a week old. The Fulmar is the bird which the St. Kildans value most highly, it being specially prized for food, for feathers, and for its oil. The old birds are snared from the nest for these purposes, though only to a comparatively limited extent, by far the greater portion of the supply being furnished by the young birds. The great Fulmar harvest commences on August 12th, when the young birds are about fully fledged, and it lasts about seven or eight days, by the end of which time most of the young birds which have not been captured have flown. The young birds are caught by hand and killed by breaking the neck, which is then twisted to keep the oil in. The oil is squeezed out of the bird by compressing the sides of the chest and the abdomen, and is received in cans taken for this purpose. The fat inside the body of the bird is taken out, melted down and mixed with the other oil. A good deal of additional oil is also obtained by skinning the bird and putting the skin with the attached fat into the melting pot, when the oil rises to the surface and is skimmed off. The oil is chiefly used for burning in the lamps, and constitutes, indeed, the sole source of light for the natives during the winter months. Some of it, however, is exported, the average quantity sent out of the island being about 40 pints for each of the sixteen houses; it realizes sixpence a pint. The feathers plucked from the bodies of the birds are handed over to the factor in payment of rent, or given in exchange for groceries and other necessaries. Fulmar feathers indeed constitute the great mass of the feathers now exported.

After the bird has been plucked, it is split lengthways down the back, the viscera removed, and then, if wanted for immediate use, it is straightway cooked (usually boiled), or else it is preserved by filling the body with salt, and packing the birds one above the other in barrels, like herrings. Great quantities of these birds, the product of the great Fulmar harvest, are preserved in this way for food during the winter months. The average number of young Fulmars taken in August amounts to between 400 and 500 birds for each of the 16 houses, or, say, about 7,500 birds altogether. Last season, however, was an unusually good one, the natives taking about 600 birds for each of the sixteen houses, or about 9,600 altogether. This harvest of young Fulmars is taken on the main island, it being seldom practicable, owing to unfavourable weather or other causes, to get to the neighbouring islands for this purpose during the limited period in which it is possible to take the young birds. This is the reason why the natives are so particular that the old birds shall not be disturbed on the main island during the nesting season, so as to ensure that the harvest there shall be a good one; but they do not scruple to snare the old birds on the nest in the subsidiary islands, and in fact take hundreds of them in that way up to the end of the period of incubation. After the August harvest is over, no more Fulmars can be got till the following spring, when the old birds can again be snared on the nests, though occasionally in March a few may be captured at night on the rocks.

The immense majority of Fulmars at St. Kilda are of the usual white-breasted form, but I saw a very few of the grey type: one of the latter, snared on the nest, was considerably smaller than the common form. The young Fulmar in first plumage (of which I had two specimens sent me after I left the island) resembles the adult in having the head, neck and under-parts pure white. It differs from the adult, however, in having the general hue of the back and upper part of wings of a uniform bluish-grey (with the exception of the primaries and primary coverts, which, as in the adult, are of a dusky slate colour); whereas in the adult many of the feathers forming the different wing coverts have their outer webs shaded to a variable extent with a light brown colour, which produces an irregular shaped pattern on the wing, which is quite conspicuous when the bird is in flight.

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