PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XV.

SESSION 1900-1901.

LIVERPOOL:

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1901.

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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.

SESSION XV., 1900-1901.

President:

Prof. PATERSON, M.D., M.R.C.S.

Vice-Presidents:

Prof. W. A. HERDMAN, D.Sc., F.R.S.
J. WIGLESWORTH, M.D., F.R.C.P.

Hon. Treasurer:

T. C. RYLEY.

Hon. Librarian:

JAMES JOHNSTONE, B.Sc.

Hon. Secretary:

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

Council:

H. C. BEASLEY.
W. J. HALLS.
Rev. L. de BEAUMONT KLEIN, D.Sc.
W. S. LAVEROCK, M.A., B.Sc.
Rev. T. S. LEA, M.A.
JOSEPH LOMAS, F.G.S.
JOHN NEWTON, M.R.C.S.
ALFRED QUAYLE.
A. T. SMITH.
I. C. THOMPSON, F.L.S.
J. M. TOLL.

REPORT of the COUNCIL.

During the Session 1900-1901 there have been seven ordinary meetings and three field meetings of the Society. The latter were held at Hilbre Island, Rossett and Gresford, and Halkin, near Holywell, respectively. The third field meeting to Halkin 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 specimens, both microscopic and macroscopic, has been a feature of the meetings.

On the invitation of Council, Prof. D. J. Cunningham, M.D., D.Sc., F.R.S. of Dublin University, lectured before the Society at the March meeting on the "Microcephalic Idiot," and in response to special invitations, sent mainly to the Medical profession, a large and appreciative audience assembled.

The Library continues to make satisfactory progress and additional important exchanges are in process of arrangement.

The Treasurer's statement and balance sheet are appended.

No alterations have been made in the Laws of the Society during the past session.

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

Honorary Members	9
Ordinary Members	53
Student Members	28
Total.........	90

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the fifteenth session was held at University College on Friday, October 12th, 1900.

The President-elect (Prof. Paterson, M.D., M.R.C.S.,) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1899-1900 (see "Proceedings," Vol. XIV., p. viii.) was submitted and adopted.
2. The Treasurer's Balance Sheet for the session 1899-1900 (see "Proceedings," Vol. XIV., p. xxxv.) was submitted and approved.
3. The Librarian's Report (see "Proceedings," Vol. XIV. p. xxviii.) was submitted and approved.
4. The following Office-bearers and Council for the ensuing Session were elected:— Vice-Presidents, Professor Herdman, D.Sc., F.R.S., and J. Wiglesworth, M.D., F.R.C.P.; Hon. Treasurer, T. C. Ryley; Hon. Librarian, James Johnstone; Hon. Secretary, Joseph A. Clubb, M.Sc.; Council, H. C. Beasley, H. O. Forbes, LL.D., W. J. Halls, Rev. L. de Beaumont Klein, D.Sc., W. S. Laverock, M.A., B.Sc., Rev. T. S. Lea, M.A., Joseph Lomas, F.G.S., John Newton, M.R.C.S., Alfred Quayle, A. T. Smith, I. C. Thompson, F.L.S., and J M. Toll.
5. Prof. Paterson, M.D., M.R.C.S., delivered the Presidential Address, entitled "Anatomy and Evolution," (see "Transactions," p. 3). A vote of thanks was proposed by Dr. de Beaumont Klein, seconded by Dr. Newton, and carried with acclamation.

The second meeting of the fifteenth session was held at University College on Friday, November 9th, 1900. The President in the chair.

1. Prof. Herdman exhibited under microscopes a series of lingual ribbons of Mollusca.

2. Mr. H. C. Robinson exhibited with remarks a small collection of Birds and Mammals from Queensland, Australia.

3. Prof. Herdman submitted the Fourteenth Annual Report on the work of the Liverpool Marine Biology Committee, and the Port Erin Biological Station (see "Transactions," p. 19).

The third meeting of the fifteenth session was held at University College, on Friday, December 14th, 1900. The President in the chair.

1. Prof. Herdman exhibited a series of marine animals, mounted as lantern slides.

2. Dr. Wiglesworth gave a note on the spread of the Fulmar (*Fulmarus glacialis*), (see "Transactions," p. 85).

3. Mr. H. C. Robinson submitted a paper on "Some problems in Zoo-geography," and referred to the peculiar distribution of certain animals and plants.

4. Mr. F. J. Cole contributed a paper on the variations in the arrangement of the spinal nerves of the Frog (see "Transactions," p. 114).

The fourth meeting of the fifteenth session was held at University College, on Friday, January 11th, 1901. The President in the chair.

1. Mr. H. C. Beasley exhibited and described some fossils (*Estheria minuta*) recently found by Mr. J. Lomas in the Trias at Oxton.

2. Prof. Herdman gave a lecture entitled "The Greatest Biological Station in the World," being an account of a recent visit to the "Stazione Zoologica" at Naples. The great importance of the work carried on at such Biological Stations was referred to, and a most interesting account was given of the Naples Station, its staff and its work. The lecture was illustrated by a number of lantern slides, including pictures of the aquarium tanks and their contents.

The fifth meeting of the fifteenth session was held at University College, on Friday, February 8th, 1901. The Vice-President (Prof. Herdman) in the chair.

1. Prof. Herdman submitted the "Report on the Investigations carried on in 1900 in connection with the Lancashire Sea Fisheries Laboratory, University College and the Sea-fish Hatchery at Piel, near Barrow," (see "Transactions," p. 126).

2. Prof. Herdman gave a note on a "Fisheries Problem," (see "Transactions," p. 141).

3. Mr. J. Johnstone contributed a paper on a "Sporozoon parasite of the Plaice," (see "Transactions," p. 184).

4. The L.M.B.C. Memoir on *Lernea* and *Lepeophtheirus*, by Mr. Andrew Scott, was laid on the table (see "Transactions," p. 188).

The sixth meeting of the fifteenth session was held at University College on Thursday, March 28th, 1901. The President in the chair.

1. Prof. D. J. Cunningham, M.D., D.Sc., F.R.S. of Dublin University gave an interesting lecture entitled "The Microcephalic Idiot." The lecturer dealt with the problems connected with the growth and structure of the skull and brain, the changes which occur in the various parts of the cerebral hemispheres, and the relation of these changes to the theory of atavism. The lecture was illustrated by a number of lantern photographs.

The seventh meeting of the fifteenth session was held at University College on Friday, May 10th, 1901. The President in the chair.

1. Paper by Mr. A. Scott on some additions to the Fauna of Liverpool Bay (see "Transactions," p. 341).

2. Paper on the Neck Glands in Marsupials, by Mr. J. Johnstone, B.Sc. (see "Transactions," p. 354).

3. The methods and results of the German Plankton Exhibition, by Dr. J. T. Jenkins (see "Transactions," p. 279).

4. Report on the Aculeate-Hymenoptera of Lancashire and Cheshire, byMr. Willoughby Gardner, F.R.G.S., (see "Transactions," p. 363).

5. Notes on (*a*) suprasternal ossifications, (*b*) the presence of eight cervical vertebræ in the human skeléton, by Prof. Paterson, M.D.

The eighth, ninth, and tenth meetings of the Society were Field Meetings and were held at Hilbre Island, Rossett and Gresford, and Halkin, near Holywell, respectively. The last named was held jointly with the Liverpool Geological Society. At Rossett and Gresford a short business meeting was held after tea. The President from the chair proposed the name of Mr. H. C. Beasley as President for the coming session. Mr. I. C. Thompson seconded and Prof. Herdman supported the motion, which was carried unanimously. Mr. Beasley briefly responded.

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 ballotted 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.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1900-1901.

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.

1886 Barron, Prof. Alexander, M.B., M.R.C.S., 34, Rodney-street.

1888 Beasley, Henry C., 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., Lea Hall, Gateacre.

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

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

1897 Dutton, Dr. J. Everett, 502, New Chester-road, Rock Ferry.

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

1894 Forbes, H. O., LL.D., F.Z.S., Free Public Museums, Liverpool.

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

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

1896 Haydon, W. H., 8, Amberley-street.

1900 Hayward, 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.

1900 Horsley, Dr. Reg., Stoneyhurst, Blackburn.

1898 Johnstone, James, B.Sc., HON. LIBRARIAN, Fisheries Laboratory, University College, Liverpool.

1886 Jones, Charles W., Allerton Beeches.

1894 Jones, Charles Elpie, B.Sc., Prenton-road, W., Birkenhead.

1895 Klein, Rev. L. de Beaumont, D.Sc., F.L.S., 26, Alexandra Drive.

1894 Lea, Rev. T. S., St. Ambrose Vicarage, Widnes.

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

1886 Lomas, J., Assoc. N.S.S., F.G.S., 16, Mellor-road, Birkenhead.

1888 Newton, John, M.R.C.S., 2, Prince's Gate, W.

1900 Nisbet, Dr., 175, Lodge Lane, Liverpool.

1894 Paterson, Prof., M.D., M.R.C.S., PRESIDENT, University College, Liverpool.

1894 Paul, Prof. F. T., Rodney-street, Liverpool.

1892 Phillips, E., L.D.S., M.R.C.S., 33, Rodney-street.

1886 *Poole, Sir James, J.P., Abercromby-square.

1897 Quayle, Alfred, 7, Scarisbrick New-road, Southport.

1890 *Rathbone, Miss May, Backwood, Neston.

1887 Robertson, Helenus R., Springhill, Church-road, Wavertree.

1897 Robinson, H. C., Holmfield, Aigburth.

1899 Ross, Ronald, J. G. H., M.R.C.S., F.R.S., University College, Liverpool.

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.

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

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

1900 Smith, Mrs., 14, Bertram-road, Sefton Park.

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

1900 Thompson, J., 3, Derwent-square, Stoneycroft.

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

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

1886 Walker, Alfred O., J.P., F.L.S., Ulcombe Place, Maidstone.

1897 Warrington, Dr. W. B., 80, Rodney-street.

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

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

B. Student Members.

Bennette, Horace W. P., Gothic Lodge, Park-road, S., Birkenhead.

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

Carstairs, Miss, Lily-road, Fairfield.

Dickenson, T., 3, Clark-street, Prince's Park.

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

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

Gill, E. S. H., Shaftesbury House, Formby.

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.
Hunter, S. F., Westminster Park, Chester.
Jefferies, F., 45, Trafalgar-road, Egremont.
Jenkins, J. T., D.Sc., University College, Liverpool.
Jones, H., University College, Liverpool.
Knott, Henry, 11, Brereton Avenue, Liverpool.
Lawrie, R. D., Sunnyside, Woodchurch Lane, Birkenhead.
Law, Arthur, B.Sc., University College, Liverpool.
Lloyd, J. T., 43, Ullet-road, Sefton Park.
Mann, J. C., University College, Liverpool.
Mawby, W., Clumber, Prenton-road, E., Birkenhead.
Pearson, J., 43, Dryden-road.
Stallybrass, C. O., Grove-road, Wallasey.
Scott, G. C., 65, Croxteth-road.
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.

H.S.H. Albert I., Prince of 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.
Leicester, Alfred, Buckhurst Farm, nr. Edenbridge, Kent.
Solms-Laubach, Prof-Dr., Botan. Instit., Strassburg.

REPORT of the LIBRARIAN.

THE only new exchange of publications arranged during the past year is with the K. Leopoldinisch-Carolinische Akademie der Naturforscher of Halle, A.S. Several other exchanges are, however, in contemplation.

The grants of £24 by the Council during the last two years have nearly sufficed to bind all the back numbers of the publications in the Library. A considerable number of new volumes are, however, received every year, and it is very desirable that a yearly vote of money should be made for this purpose.

Lists are given below of the publications added to the Library during the last year, and of the Societies and Institutions with which publications are exchanged.

List of publications added to Library during the Session 1900-1901:—

Amsterdam, Jaarboek K. Akademie Wetenschafpen. 1899.

Amsterdam, Verhand. K. Akademie Wetensch. (Ser. 2). Deel VII., Nos. 1-3. 1899-1900.

Amsterdam, K. Akad. Wetensch. Verslag gewone Vergad. Wis-en Natuurk. Afdeeling. Deel. VII. 1900.

Amsterdam, K. Akad. Wetensch. Proc. of The Section of Sciences. (English Translation of above). Vol. II. 1900.

Baltimore, Memoirs Biol. Labt., Johns Hopkins University. Vol. IV. —No. 1—IV. 1898-1900.

Baltimore, University Circulars. Vol. XIX., No. 146. 1900.

Berlin, Sitzungsb, k. Akad. Wissench. Jahrg. 1900. Nos. I.—LIII.

Bergen, Bergen Museums Aarbog. 1899, 1900.

Bergen, Bergens Museum Aarsberetning for 1899 and 1900-1.
Bergen, Crustacea of Norway, G. O. Sars. Vol. III., Parts 5—10, 1900.
Birmingham, Proc. Nat. Hist. and Phil. Society. Vol. X.—XI. 1896-9.
Bordeaux, Proces. Verbaux Soc. Linn. Vol. LIV. 1899.
Bonn, Sitzungsb. Niederrhein. Gesell. 1899 (2), 1900 (1).
Bonn, Verhandl. Naturhist. Vereins. Jahrg. 56 (2), 1900 (1).
Bologna, Rendiconto. Accad. Sci. N.S. Vols. II. and III. 1898-9.
Bologna, Memorie R. Accad. Sci. Ser. V. Tom. VII.—
(*a*) Sezione di Medicina e Chirurgia.
(*b*) Sezione delle Scienze Naturali.
Boston (U.S.A.), Proc. Soc. Nat. Hist. Vol. 29. Nos. 9, 11-14. 1900.
Buenos Aires, Comunicaciones Mus. Nac. T. I., Nos. 6 and 7, 1900.
Cambridge (U.S.A.), Bull. Mus. Comp. Zool. Vols. 35, No. 8; 36, Nos. 1—6; 37, Nos. 1—2.
Cambridge (U.S.A.), Annual Report Mus. Comp. Zool., Harvard. 1899-1900.
Chicago, Fifth Annual Report of the John Crerar Library.
Chicago, Field Columbian Museum Publications—
Anthropological Series. Vol. I., No. 1; Vol. II., Nos. 1—3. 1895-8.
Zoological Series. Vol. I., Nos. 2—18. 1895-99. Vol. 3, Nos. 1—2, 1900.
Ornithological Series. Vol. I., No. 1—2. 1896-7.
Geological Series. Vol. I., Nos. 1—7. 1895-1900.
Botanical Series. Vol. I.; Vol. II., Nos. 1—3. 1895-1900.
Report Series. Vol. I., No. 1—5. 1895-99.
The Authentic Letters of Columbus. W. E. Curtis. 1895.
Birds of Eastern N. America. Pts. 1 and 2. C. B. Cory. 1899.
Chicago, The Botanical Gazette. Vols. 13—27, 1888-99. Vol. 30, Vol. 31, Pts. 1—2.
Christiania, Nyt. Magazin for Naturvidenskaberne. Bd. 38. Hefte 1. 1900.
Christiania, Oversigt Vidensk. Selskabs. 1899.
Christiania, Videnskabs-selskabs Forhand. 1899. Nos. 2—4.
Dublin, Scientific Proc. Roy. Dublin Soc. Vol. IX., pts. 1—2. 1899-1900.
Dublin, Economic Proc. Roy. Dublin Soc. Vol. I., pts. 1—2. 1899.
Dublin, Index Proc. and Trans. Roy. Dublin Soc. 1877-98.
Dublin, Trans. Roy. Dublin Soc. Vol. VII., pts. 2—7. 1899-1900.
Edinburgh, Trans. Scottish Nat. Hist. Soc. Vol. I., pt. 1. 1900.
Edinburgh, Proc. Roy. Soc. Edinburgh. Vol. XXII., 1897-99.

Edinburgh, Laboratory Reports, Roy. Coll. Physicians. Vol. VII., 1900.

Frankfurt, A.M., Bericht Senck. Naturf. Ges. 1900.

Freiburg, Ber. Naturforsch. Gesell. Bd. 11. Heft 2. 1900.

Glasgow, Trans. Nat. Hist. Soc. Vol. 6 (N.S.), pt. 1. 1901.

Glasgow, Millport Biological Station. Communications I. 1900.

Glasgow, 18th Report Scottish Fishery Board. 1900.

Gottingen, Nachrichten Konig. Gesellsch. Wissensch. Math.-Phys., Klasse Hefte 1—4, 1900.

Gottingen, Gesch. Mitt. Hefte 1—2. 1900.

Habana, El Azucar como alimento del Hombre. Dr. y Costa.

Habana, La Legislacion Sanitaria Escolar. Dr. y Costa.

Hannover, Mittheil. Deutsch. Seefischerei. Vereins. Bd. 16; 17, Nos. 1—3.

Haarlem, Arch. Mus. Teyler. Ser. 2. Vol. 7. Pt. 2. 1900.

Halifax, Proc. and Trans. Nova Scotian Inst. Sci. Vol. X., pts. 1-5. 1899.

Kjobenhavn, Oversigt K. Danske Vidensk. Selskabs. 1900, Nos. 2—6, 1901, No. 1.

Kjobenhavn, Mem. Acad. Roy. Sci. Denmark. Ser. 6, t. 9, No. 6. 1900.

Kjobenhavn, Report Danish Biological Station. IX. 1899.

Kjobenhavn, Vidensk. Meddelelser. Aar. 1900.

Kjobenhavn, Fortegn. K. Danske Vidensk. Selskabs. Jan., 1901.

Kjobenhavn, Beretning Komm. for Vidensk. Undersogelse. Danske. Farvande.

Kiel and Leipzig, Wissensch. Meeresuntersuchungen. Bd. 3. Heft 1. Bd. 4. Heft 1. 1900.

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List of Societies, etc., with which publications are exchanged (additions made during current session marked with an asterisk) :—

AMSTERDAM.—Koninklijke Akadamie van Wettenschappen.
Koninklijke Zoölogisch Genootschap Natura Artis Magistra.

BALTIMORE.—Johns Hopkins University.
BATAVIA.—Koninklijke Natuurkundig Vereeniging in Ned. Indie.
BERGEN.—Museum.
BERLIN.—Konigl. Akadémie der Wissenschaften.
Deutscher Fischerei-Vereins.
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BOLOGNA.—Accademia delle Scienze.
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BOSTON.—Society of Natural History.
BRUSSELS.—Académie Royal des Sciences, &c., de Belgique.
BUENOS AIRES.—Museo Nacional.
Museo de la Plata.
CAEN.—Société Linnéenne de Normandie.
CAMBRIDGE.—Morphological Laboratories.
CAMBRIDGE, MASS.—Museum of Comparative Zoology of Harvard College.
CHICAGO.—Field Columbian Museum.
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.
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HALIFAX.—Nova Scotian Institute of Natural Science.
HAARLEM.—Musée Teyler.
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HELIGOLAND.—Königliche Biologische Anstalt.
KIEL.—Naturwissenschaftlichen vereins fur Schleswig-Holstein.
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LONDON.—Royal Microscopical Society.
British Museum (Natural History Department).
MANCHESTER.—Microscopical Society.
Owens College.
MARSEILLES.—Station Zoologique d'Edoume.
Musée d'Historie Naturelle.
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MELBOURNE.—Royal Society of Victoria.
MONTEVIDEO.—Museo Nacional de Montevideo.
MONTPELLIER.—Académie des Sciences et Lettres.
MOSCOU.—Société Impériale des Naturalistes.
NANCY.—Société des Sciences.
NAPOLI.—Accademia delle Scienze Fisiche e Matematiche.
NEW BRUNSWICK.—Natural History Society.
OPORTO.—Annaes de Sciencias Naturaes.
PARIS.—Museum d'Histoire Naturelle.
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Société de Biologie.
PHILADELPHIA.—Academy of Natural Sciences.
PLYMOUTH.—Marine Biological Association.
ST. LOUIS, MISS.—Academy of Sciences.
ST. PETERSBURG.—Académie Impériale des Sciences.
SAN FRANCISCO.—California Academy of Science.
SANTIAGO.—Société Scientifiq du Chili.
STAVANGER.—Stavanger Museum.
STOCKHOLM.—Académie Royale des Sciences.
SYDNEY.—Australian Museum.
TOKIO.—Imperial University.
Zoological Society of Tokyo.
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TORONTO.—Canadian Institute.
TRIESTE.—Societa Adriatica de Scienze Naturali.

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Société Royale des Sciences.
WASHINGTON.—Smithsonian Institution.
United States National Museum.
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WELLINGTON, N.Z.—New Zealand Institute.
WIEN.—K. K. Naturhistorischen Hofmuseums.
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TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

A

INAUGURAL ADDRESS

ON

SOME ANATOMICAL PROBLEMS BEARING UPON EVOLUTION.

By Prof. PATERSON, M.D., President.

[Read October 12th, 1900.]

Introduction.

My first duty is to thank the Liverpool Biological Society for the compliment paid to me in my election to the post of President for the current Session. It is a great honour to preside over this society, which under the guidance of many enthusiastic Naturalists has attained a position in the district and in the wider sphere of natural science of which it may well be proud: and it is a great honour to succeed men who have previously occupied this chair, men respected and distinguished for their knowledge and their original work.

In an ideal state the President of this Society would know everything about something and something about everything. In reality I suspect all your previous Presidents would admit absolute ignorance of many things and partial knowledge of a few. In this respect I feel fully equal to the standard of excellence required. Indeed it is in truth the ever narrowing specialism of Biological science which most of all justifies the existence of such a society as this. Each of us is apt to follow his own solitary pathway of thought to the neglect of the pursuits of others. One of the main objects of our meetings here is to break down the barriers raised by separate investigation, by collectivism to improve on individualism, by sympathy to widen knowledge. One common aim inspires us all—to define the action of organic forces, to reduce order out of apparent chaos, to peer as deeply as we can into the well of Truth.

It is with special pleasure that I come before you to-day. It is a particular gratification to an anatomist to have the opportunity of discussing with a sympathetic audience some of the difficulties and puzzles that confront him in his special department of Biology.

The study of animal morphology is overshadowed by the doctrine of evolution, and the theory must admittedly be tested and tried by the searching light of structure and development. Palæontology looks ever backward. Functions may change, and be transferred to structures of an alien pattern. Structure is always reliable. The matter of the origin of species cannot be said to be conclusively settled. There are many points in vertebrate anatomy which bear upon it, and it is to a few of these points that I wish to direct your attention for a while to-night.

The thought has occurred to me that the question of the individuality, or the transmutability of species might be settled definitely by a study of some of the lowest forms of life, such as Bacteria; but if after the exhaustive study of such primitive forms the subject is still baffling, how much greater difficulty does it present when we are concerned with complex and highly organised animals, such as Vertebrates.

Vertebrate Architecture.

In any study of comparative anatomy our primary object is to decide upon the principal features, the plan of architecture of the animals in question.

Among vertebrate animals obviously the most characteristic features are a tubular structure, bilateral symmetry and segmentation.

SEGMENTATION.

It is of one of these characteristics—segmentation—that I wish to speak a few words. We are rather apt, in my opinion, to attach too much importance to this one feature. We are inclined, I think, to regard vertebrate segmentation as a primary feature, whereas although it is doubtless fundamental and essential, it is really a secondary event or process in the architecture of the animal. There is a still more elementary plan of structure in the vertebrate to which the process of segmentation is superadded and applied.

The most primitive plan—the essential architecture—of the vertebrate organism is to be seen in the longitudinal series (median or lateral) of structures which constitute the organs of the body, the notochord, central nervous system, alimentary canal, vascular and genito-urinary organs. These structures are all in their origin unsegmented, and are only secondarily and partially affected by the segmental process.

Herbert Spencer makes the luminous suggestion that segmentation has arisen on account of the necessities of life, for feeding or protection; that lateral cleavage is produced by the stress and strain laid upon a tubular organism in its efforts at locomotion.

As a matter of fact, in the embryo the segmental process begins with the formation of organs concerned in the production of a locomotor mechanism—the myotomes or muscle-plates—which eventually produce the axial muscles and the axial skeleton.

Closely connected with, and immediately subsequent to, the formation of these plates, the nerve roots arise from the spinal cord in pairs, and directed between the myotomes retain in their peripheral course a definitely segmental arrangement, which becomes fixed and stereotyped by the formation at a later period of the vertebral column.

Not only the muscular and nervous systems, but other organs and systems become stamped by secondary characters of the same kind, notably the vascular and genito-urinary systems, producing series of segmental vessels and segmental tubules, all be it noted, derived from the same mesoblastic germinal layer.

At the same time it must be borne in mind that the essential feature is a longitudinal series of organs, and that the segmentation of the vertebrate is neither constant throughout its length, nor necessarily complete at any point.

Time will not permit me to illustrate this point fully, but I may be allowed to refer to one or two organs and systems in passing.

The Axial Skeleton—The vertebral segment is never complete even in the skeleton. The nearest approach to it occurs in the thorax, but even here (in mammals) the sternum is interposed to fill up the deficiences of the segmental process, as a longitudinal element which completes the thoracic skeleton. In limbless reptiles the deficiency remains, and the ribs terminate in free ends.

The secondary nature of segmentation is illustrated by the development of the spinal column in rodents. In the rat at birth, when the cartilaginous elements of the skeleton are defined, and the process of ossification is well advanced, the bodies of the vertebræ are not segmented off from one another. They are merely constricted at intervals, and the whole series form a kind of thick tubular investment for the notochord.

There are further certain obvious instances in which segmentation is arrested: *e.g.*, in the cervical vertebræ of cetacea, and in the human sacrum. The best instance of all is in the cranium, where there is no clear evidence at all of osseous segmentation, but instead the formation of a laminar *basis cranii.*

Even accepting the essential character of the process, the value and importance of segmentation are diminished when a comparison is made to show its effect in the construction of a large group of animals. We are familiar with the subdivision of the mammalian spinal column into regions—neck, chest, loin, pelvis and tail. The causes producing this differentiation are numerous, and are correlated with other differences in the skeleton—site of limb attachment, tail development, length of body required for the reception of viscera, &c. Among mammals there is no constancy or definition of the number of vertebral segments in any region of the spine. Even in the neck, where there is greatest constancy, exceptions to the rule occur. We cannot explain these differences, which are fundamental and essential, and are associated with other deep-seated differences of structure.

The Peripheral Nerves.—Reference has already been made to the segmental character of the peripheral nerves: but even in this case the metameric arrangement is not carried out completely, either in the origin or the termination of the nerves. There is no definite segmentation of the grey matter of the spinal cord; on the contrary, the nerve roots overlap, and have relations with considerable tracts of cord on each side of the point of entrance. Similarly in their distribution, while some motor nerves have necessarily a segmental termination in segmental (intercostal) muscles, as a rule the segmental arrangement of the nerves is obliterated or confused by the formation of plexuses and the distribution of several spinal nerves to a particular muscle or area of skin.

These nerve plexuses produce by a combination of neighbouring segmental nerve trunks, a series of nerves of distribution to peripheral areas of skin or muscles, which constitute a motor and sensory mechanism for the whole of the district and for the district as a whole with which the plexus is concerned. This is well illustrated by the arrangement of the limbs, to which attention will be directed later on.

But it is further remarkable that just as the segmental character of the nervous system is most pronounced (as might be expected) where the segmental skeleton is most apparent—in the region of the thorax—so in the head region, where osseous segmentation is virtually absent, the segmental nature of the nerves is most doubtful and confused. I do not wish to wander into any fields of speculation about the cranial nerves to-night, but only name them as illustrating the breakdown of segmental characters even in the nervous system, and the close association of certain of them (which are most like spinal nerves) with segmental motor mechanisms or organs, *e.g.*, the third, fourth, sixth, and twelfth nerves, which are the motor nerves to muscles derived from the cephalic myotomes.

The Nature of Limbs.—A study of the structure of the limbs of vertebrates shows the influence that this idea of segmentation has upon morphologists. Owen, that greatest of modern comparative anatomists, regarded the limbs as offshoots from the costal arches.

Pinning our faith on segmentation, we may evolve the mammalian limb, in imagination, in the following way:—We may start with the segmental parapodia of the annelid. Amphioxus gives us a further advance with a lateral fold, segmented and therefore representing possibly a fusion of these segmental elements. The evanescent wolffian ridge, with its permanent pectoral and pelvic limbs in higher vertebrates, may represent the vestige of this lateral fold: the limbs of elasmobranchs and other fishes, with their more numerous nerves, representing a lower stage of evolution than the limbs of reptiles, birds, and mammals, in which fewer nerves (and therefore segments) are engaged.

Unhappily this theory lacks adequate proof. In the mammalian limb at least the only strictly segmental structures engaged are the nerves, and they, as pointed out already, lose their segmental character for the most part owing to the formation of the limb-plexuses.

The mammalian limb is formed as a flap or fold of undifferentiated mesoblast, in which the skeleton formation arises as a cartilaginous core, surrounded by strata of cells from which the muscles of the limb are produced. The vessels arise *in situ*, and although ultimately the structure of the limb, as far as its muscular system is concerned, is related (indirectly) to the segmental muscle-plates, the nerves are our only guides to the segmental character of the limbs, as Goodsir first pointed out.

There have been many efforts to trace these segmental nerves through the plexuses and through the limbs. I do not propose to enlarge to-night upon the work that has been done by anatomists, physiologists and clinicians in this field; but we have now a fairly clear picture of the significance of a limb plexus. We know that a plexus does not mean confusion of distribution. It can be made out by careful dissection, by experiment and by clinical observation that the chief occurrence in the formation of a plexus is (1) the division of a series of spinal nerves into subordinate cords, and (2) the union of these subordinate cords (large or small) with one another, so as to produce a series of nerves for the innervation of the limb in such a way that different impulses from a particular area or spot may be able to stimulate a wider tract of the spinal cord, and motor impulses from a particular central point may reach more than one muscle, as a given muscular nerve is known to contain fibres from more than one spinal nerve, and a given spot of skin is similarly known to be innervated by more than one spinal nerve. In other words, a limb plexus is a nerve-organ for the supply of the limb as a whole, and for the whole limb, providing for the adequate reception of different impulses and for the proper regulation of muscular action. There is further a morphological significance in the upbuilding of the limb plexuses, in which the segmental arrangement is shown, although faintly. Here then, without going further, we have an instance of the value of segmentation in vertebrate architecture. In elasmobranchs, and in reptiles, it appears certain that the muscular apparatus of the limbs is derived directly from the myotomes. In birds and mammals the segmental character of the limb muscles is obliterated, and they arise *in situ* from undifferentiated mesoblast. In all vertebrates the nerves are segmental. As in the trunk so in the limbs in their most primitive condition, it is the locomotor mechanism which shows evidence of a segmental origin. But in the mammalian limb, as in the muscular system, so with regard to the nerves, the segmental process is, so to speak, discarded when its work is done. Although the segmental character of the nerves can be traced even in their ultimate distribution to muscles and nerves, yet this feature is partially obliterated, and is forced into a less conspicuous position by the still more fundamental and essential characteristics of the mammalian limb.

The Value of Segmentation.—In fine, segmentation may be looked upon as a process which stamps the vertebrate organism with certain definite features, but is not necessarily the essential plan of its organisation. It is a process liable to be controlled, modified, and curtailed by other causes, and by the action of other principles in the growth of the animal. It is a valuable guide up to a certain point, but other principles have to be taken into account as well, in making a wide or general comparison of even vertebrates alone. Segmentation is a factor in organic growth which is utilised as far as is needed, but the extent to which it is carried varies extraordinarily in different animals and in parts of the same animal. The process of segmentation moreover is superadded to the still more fundamental style of architecture, the longitudinal tubular arrangement of the essential organs of the body.

Embryological Difficulties.

The problem of evolution also faces us in the study of the growth and development of an animal. Of course among vertebrates and more particularly mammals, we are dealing with structures highly specialised and complicated. But the problem is essentially the same as in simpler forms,—to understand what determines the differentiation of the cellular constituents of the organism, because ultimately this cellular differentiation is the cause of the individual and specific characters of a particular form—the leopard's spots and the Ethiopian's skin.

A complex organism is built up of organs. Its organs are composed of tissues, and its tissues of cells and their derivatives. In the skeleton there are a series of structures which are obviously, from their size, durability and importance in the animal economy, of the greatest use in the study of comparative anatomy. In comparing one animal with another, or making out the homologies of their structure, a basis of comparison must be taken either in the adult bones, or in some embryonic condition of the skeleton common to both animals.

I have recently made a study of the development of the breast-bone, and have realised the difficulties which beset this subject in relation to the development of the tissues in the embryo. Like the rest of the skeleton, the sternum begins as myxomatous mesoblastic tissue. Its cells become more closely conglomerated together to form a longitudinal streak or strand of cells (associated at the head end with the developing clavicle.) This cellular band is joined by the ribs, and becomes converted into hyaline cartilage, around which the formation of bone occurs, gradually converting the cartilaginous sternum into blocks of osseous tissue.

I hope to have another opportunity this winter of discussing the morphological questions connected with this study. At present it is enough to point out how it illustrates the depth of the difficulty surrounding the evolution of any organism. Here we have a highly complex process occurring not by chance, or apparently on account of extraneous circumstances, but spontaneously, and in consequence of the inherent vital capacity of the constituent cells, due to the arrangement of their atoms, to their chemical activity, in short, to the functions of protoplasm.

There appears to be more predestination than free will in embryology, and not only the plan of the building, but also the materials used are of a regular, definite pattern.

The Significance of Anatomical Variations.

One of the strongest arguments in Darwin's theory of the origin of species is the capacity of individual organisms for variation. I would like for a moment to refer to this subject, and to inquire what bearing the occurrence of anatomical variations may be said to have upon the general problem.

Anatomists, from a minute study of a single species, are tolerably familiar with the extent and importance of these variations from the normal. We are all aware how the monotony of the anatomist's day is varied by the occasional mild excitement caused by the occurrence of an abnormality. It is gravely handled by the professor, examined by the demonstrators, and enthusiastically dissected by the student, until eventually the excitement subsides and the specimen is gone.

Variations may be gross or refined, teratological or anatomical. If any philosophical significance attaches to the occurrence of variations, if they are stepping-stones in the pathway of evolution, teratological variations of such a kind as to interfere with the vital functions of the individual, might be expected to disappear through want of inheritance.

Even gross variations can, however, be traced, as a rule, to an excess or arrest of development along the usual lines. They thus have a distinct value (and this is their only scientific value, in my opinion) in corroborating and confirming the path of development of the organ in question (*e.g.*, cleft palate, spina bifida).

The development of the kidney and ureter has been in recent years subjected to fresh study, with the result that the accepted view of their formation has been doubted. Such a teratological example as a rudimentary kidney and a separate rudimentary ureter, lends support to the orthodox view of the formation of the two organs from separate elements.

The occurrence of variations great and small alike raises some unanswerable questions.

Twins.—Do twins occur merely as sports to increase the gaiety of nations? Or are they extreme examples of a fertility that, occurring in a lesser degree, produces double monsters? Or, again, does their occurrence associate man phylogenetically with any group in which a pair of young is the normal occurrence?

Vigour or Decline.—The female elephant, in certain of its organs—the anthropoid apes, in certain characters of the skeleton, exhibit extraordinary and striking variations. Do such conditions illustrate a progressive tendency, or a tendency towards degeneration and decline? They may be due to a restlessness of disposition caused by excessive vigour, or a flickering vitality, a lack of proper direction and correlation of the forces responsible for the growth of the organism.

The Significance of Variations.—The share of variations in determining the relationships of species, in deciding the avenue of evolution of an organ or an individual, in even fixing the path of development of an organ in a single species, is, in my opinion, of comparatively small account. Variations *per se* appear to me to have no more power in the production of specific alterations than the waves beating on the shore in grinding corn.

Excessive development (*e.g.*, double thumb) is not necessarily an advance in development, and vice versâ. The variation produced may be something quite remote from the disturbance in development which causes it (*e.g.*, Meckel's diverticulum). One variation (*e.g.*, supracondyloid process) may be of little account to the individual; another (*e.g.*, patent foramen ovale) is of profound importance. A given variation may be common in one species, rare in another (*e.g.*, lateral alterations in the attachment of the ilium and sacrum).

Again, taking two variations in opposite directions in a given organ, is the commoner variation of more importance than the rarer? Does the more frequent illustrate a tendency in a particular direction on the part of the species in which it occurs? Are we justified in concluding that of the two, that variation which occurs in 65 per cent. indicates progressive change, and the opposite, which occurs in 45 per cent., marks retrogressive change in the species?

Teeth.—For example, it is much more common to meet with individuals whose teeth are below the normal number by reason of the rudimentary character of the wisdom teeth, than those whose teeth exceed the normal number. From this may we infer the existence of a tendency towards diminution in the number of teeth? Yes, we may, if the inference is strengthened by the comparison in size, form and number of the teeth of man and other mammals.

Hair.—It is similarly more common to find a diminution in the extent and quantity of hair than an excessive growth on head, face or body. It may therefore be inferred that man is gradually becoming less hairy, an inference supported by comparative anatomy.

Osseous Variations.—For the most part, however, such inferences must be taken with the greatest caution, and in regard to most of the variations which occur no such inferences are possible. No evidence of the existence of a special tendency exists. Osseous variations appear to have a significance only within the narrowest limits. For example, in the vertebral column two classes of variations occur—correlated variations in the number of vertebræ in each region, and unilateral variations of individual vertebræ. The causes producing these variations are numerous, and may act separately or together.

The correlated changes in coccyx and sacrum are due to atrophy of the caudal vertebræ, along with fixation of the pelvis, the erect attitude, &c. Correlated variations of the thoracic and lumbar vertebræ are dependent upon elongation or diminution of the length of the trunk, possibly associated with differences in the size and rate of growth of viscera, and upon the separation or approximation of the region of the attachment of the limbs.

Lumbo-sacral variations are associated with the mode of attachment of the hip-bone to the spine, and present an excellent example of individual variation. Rosenberg has formulated the theory of a phylogenetic shortening of the vertebral column by a telescoping of the spine on the hip-bones, and bases his view in part upon the fact that among the variations in this region there are examples of four instead of five lumbar vertebræ, the fifth being absorbed into the sacrum, and providing an attachment of the ilium.

When however we examine a large series of human spines and sacra, we find that an excessive number of præsacral vertebræ (25) is as common as a diminished number (23). If numbers are of any account—and in a democratic age every vote has the same weight—these variations indicate as great a tendency to elongation as to shortening in the length of the spine. Rosenberg looked upon the form of spine with an excessive number of præsacral vertebræ as "atavistic," that with a diminished number as a "future" form. The plain fact is that we have here a mere individual variation, indicating an oscillation of the hip-bone round its normal attachment. It may in such cases (which occur equally in both directions,—5·3 per cent.) catch on the 24th (last lumbar) vertebra, or it may miss its connection with the 25th (first sacral) vertebra.

Similar variations occur in birds, reptiles and fishes, and in the light of comparative anatomy, and of the concomitant and correlated variations in other organs (*e.g.*, the nervous system) their morphological value becomes extremely restricted. They are indeed merely individual variations in the attachment of the limb to the trunk.

Muscular and Vascular Variations.—Similarly with other organs and systems, the capacity for variation is restricted to narrowly prescribed limits. In the muscular system the complexity of structure and arrangement is so great that any variation, as a rule, implies the minutest change in the complexity of the system. All the muscular variations possible taken together give no clue to the evolution of the system or the ancestry of man. A deficiency of the diaphragm may recall the reptile; but on the other hand, it may only be an individual example of arrested development.

The variations in the vascular system are of comparatively small importance morphologically if we except the great vessels. The mode of formation of blood-vessels and their habit of inosculation, allow readily of variation, mainly because of the occurrence of concomitant variations in neighbouring structures. Any slight obstruction will cause an alteration in the origin and course of an artery.

The Value of Anatomical Variation.

Variations appear thus to be unreliable guides except within narrow limits. They are exceptions that prove the rule. From abnormalities great or small, we are not justified in drawing any large conclusion. They serve to corroborate or confirm the mode of development of an organ. They serve to indicate morphological or physiological disturbance in the district in which they occur, just as abnormal population statistics are a symptom of abnormal conditions of life. A high death-rate means an unhealthy environment. An abnormal relation of the sexes occasionally occurs, *e.g.*, at Southport. In Scotland generally the excess of marriageable females (15 to 45) is 2 in 1,000; in Dundee the excess is 78 in 1,000. This is due not to the special attractiveness of the Dundee males, but to an alteration from normal industrial conditions, and the almost exclusive employment of female labour in the Dundee mills, or, as in Southport, to the absence of industries for marriageable males.

Variability is something inherent in all growing organisms. It is a sign of vitality and individuality. It has no significance in determining affinities with other species, or in suggesting the existence of any tendency, except the tendency to vary. At the same time the capacity for variation is extremely limited for organ, individual or species.

One of the most striking phases in which the individuality and vitality of our race is shown is in what may be called theological variability. In the Protestant Church, freedom of thought naturally gives scope to this characteristic, and leads to the production of minor differences of thought and creed; different variations of the same idea, strangely limited, strangely active, but withal not apparently capable of affecting any fundamental change in the national temper or the national character.

FOURTEENTH ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE

AND THEIR

BIOLOGICAL STATION AT PORT ERIN.

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

There is nothing remarkable to record in regard to the educational aspects of the work at the Station during the past year; but all lines of work have been continued, and all investigations have advanced a stage. Four L.M.B.C. Memoirs have been published, Volume V. of the "Fauna" has been issued, meetings have been held at the Station both for scientific purposes and to promote the interests of the insular fisheries, dredging and other expeditions have taken place, nearly all our usual workers —Mr. Thompson, Mr. Walker, Miss Thornely, Mr. Lea, Mr. Leicester, Mr. Scott, and others have continued their researches, and with their help the Curator has prepared a series of distributional charts which will be of use locally to those who visit the laboratory and collect in the neighbourhood, and will also have a wider interest to all who study the distribution of shallow water marine animals as affected by depth, nature of sea-bottom and other conditions.

The Station Record.

During the past year the following naturalists have worked at the Biological Station, in addition to the Curator (Mr. H. C. Chadwick) who has been in constant attendance with the exception of a fortnight's holiday in May.

DATE.	NAME.	WORK.
January	Rev. T. S. Lea	Photography.
March 23rd to April 23rd	Mr. F. J. Cole	Tunicata and General.
June 12th to July 4th	Rev. T. S. Lea and Mrs. Lea ...	Marine Algæ and Photography.
June 26th to July 2nd	Mr. C. E. Jones	Marine Algæ.
July	Mr. I. C. Thompson	Copepoda.
—	Mr. A. Leicester	Mollusca.
July 2nd to September 4th	Mr. L. St. George Byne	Mollusca.
August 23rd to September 18th	Mr. F. W. Headley	General.
September 1st to October 16th	Mr. E. T. Browne	Medusæ.
September	Mr. C. Turner	General.
—	Prof. Herdman	Tunicata.
—	Mr. I. C. Thompson	Copepoda.
September 29th to October 3rd	Mr. H. Yates	Polychæta.
October	Mr. I. C. Thompson ... ... Prof. Herdman	Official.
November	Mr. I. C. Thompson ... ... Prof. Herdman ... ... Mr. R. Okell...	Official.

There have also been many visitors to the Station, including the President and Members of the Isle-of-Man Natural History and Antiquarian Society, Deemster Kneen, Deemster Moore, the High Bailiff of Peel, the High Bailiff of Castletown, Mr. Justice Shee, the Principal, Masters and boys from King William's College, and many others.

Curator's Report.

"No effort has been spared to keep the instruments and apparatus in the Laboratory in an efficient condition, and excepting one of the larger dredges, no appreciable loss or damage has occurred in connection with their use. The larger Shellbend boat is still, after four seasons' use, in a sound and seaworthy condition. At the close of the season some slight repairs were found necessary, and were easily effected on the spot. The boat was then thoroughly cleaned and re-varnished. The smaller Shellbend boat has not proved quite so serviceable, and repairs by the builder were recently found necessary. The boat is at present at Chester.

"A few additions have been made to the Library during the past year, for which we are indebted to Mr. F. W. Headley and others. There is still room in the bookcase, and further donations from authors and others will be very welcome.

"The Aquarium has attracted over 350 visitors during the season, a number slightly larger than that recorded last year, and it has again been the means of interesting many in the aims of the Committee and the work of the Station, and extending their knowledge of marine life.

"During the early spring I cleaned and remounted the collection of marine shells presented some years ago by Mr. G. W. Wood. They are now exhibited in the glass cases fixed to the wall between the tanks on the upper floor, and each species bears a label on which its local and general distribution is stated.

"At the end of March four small lobsters were presented by M. E. Crebbin, and were placed in the tanks along with one captured by myself. Of these three are still living, the others having died during the process of shell-casting. I have fed them occasionally with fresh fish, but shore, edible and hermit crabs appear to be favourite food. The habit of concealing food in the gravel at the bottom of the tank, noticed in last year's

Report, has been practised by all the specimens. A small conger captured in March is still alive and healthy. For some weeks after capture it refused food, but it has since taken the Polychæte worms, *Nephthys* and *Nerine,* with avidity. The hermit crab (*Eupagurus bernhardus*), which it attacks and drags from its shell with great persistence appears to be a favourite food, and its latest gastronomic feat was to swallow a small specimen of its own species, about one-third its own size. When not at once seen by the conger, the worms dropped into the tank begin to burrow in the gravel at the bottom. In preference to seizure of the projecting tail end of the worm, the fish drives its snout into the gravel in search of the head with such force that the impact can be distinctly heard when standing some feet from the front of the tank.

"We are indebted to the Rev. T. S. Lea and Mr. G. J. Warner (of Widnes) for their kindness in repairing the Tangye pump, and to the latter gentleman for rubber unions and tools with which to connect the hose with the pump.

"The meteorological observations have been recorded with regularity, but call for no special comment.

"Shore collecting and dredging has been carried on by myself and other workers throughout the spring and summer, and amongst the more interesting captures may be mentioned the Nudibranchs *Doris diaphana* and *Hero formosa*, the former taken by Mr. Cole during the low spring tides at the beginning of April, and the latter in autumn by dredging in Bay Fine and also S.E. of the Calf in 20 faths. Both are additions to our local Fauna. Tow-netting has been carried on throughout the year, and the sequence of organisms observed has corresponded closely with that stated in the Summary published in last year's Report. A remarkable diminution in the quantity of organisms, especially of Copepoda, was noticed about the middle of July and from that time onwards to the end of September. I saw only three specimens of *Aurelia aurita,* usually so abundant, within the limits of the bay during the summer, and *Beroë ovata,* abundant in July and August last year was not seen at all.

"I have a few corrections to make in the list I gave in last Report:—The Siphonophore recorded last year as *Agalmopsis elegans* has been identified by Mr. E. T. Browne as *Cupulita sarsii.* It has been less common this year than last. The Ctenophore recorded as *Hormiphora* proves to be *Pleurobrachia,* and that recorded under the latter name is, I find, *Bolina.* The only addition to the Plankton Fauna is *Arachnactis albida,* of which the near relative *A. bournei* was recorded last year."

[H. C. CHADWICK.]

DREDGING EXPEDITIONS.

Many dredging, trawling, and tow-netting expeditions have taken place in sailing boats, larger rowing boats, and our own "Shellbend" punts in the immediate neighbourhood of Port Erin throughout the year, and the results have been recorded by the Curator in the distributional charts referred to further on (see p. 39). Boat collecting expeditions at time of spring tides from Port St. Mary to the Great Caves at the Sugar-loaf Rock and to the "Clets" in the Calf Sound, have also been carried out with success.

On September 13th we hired the steam trawler "Rose Ann" from Mr. Knox, of Douglas, and had an excellent day's work, chiefly to the east and south of the Calf Island, dredging and trawling in depths of from 15 to 30 fathoms. All the workers at the Station joined in the expedition. It was a beautiful day at sea. We worked hard all day, and much "spoil" was captured and brought back. We drew up a long list of the animals observed during the day, from which I pick out the following species to give some idea of the fauna investigated:—

Alcyonium digitatum, *Sarcodictyon catenata*, *Antennularia antennina*, and *A. ramosa*, *Sertularia abietina* and *S. filicula, and* other Hydroids (see below, p. 30), *Campanularia verticillata*, *Adamsia palliata*, *Stichaster roseus*, *Porania pulvillus*, *Palmipes membranaceus*, *Spatangus purpureus*, *Thyone fusus*, *Carinella aragoi*, *Chaetopterus variopedatus*, *Halosydna gelatinosa*, *Filograna implexa*, *Crisidia cornuta*, *Cellaria fistulosa*, *Porella concinna*, and many other Polyzoa

"Sugar Loaf" Rock, near the Chasms.

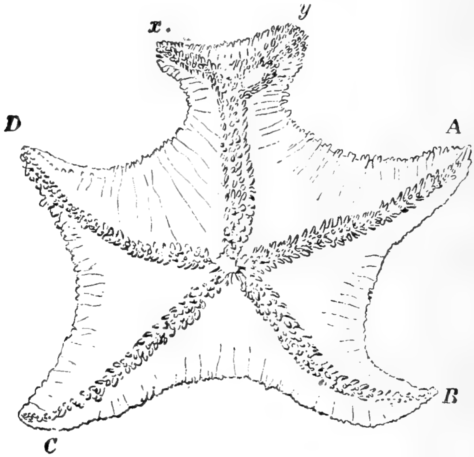
(see special lists below, p. 30), *Crania anomala*, *Gnathia dentata*, *Iphimedia eblanæ*, *Ebalia tuberosa*, *Munida rugosa*, *Pagurus prideauxii*, *Xantho rivulosa*, *Eurynome aspera*, *Pecten testæ*, *P. tigrinus*, and *P. pusio*, *Lima elliptica*, *Astarte sulcata*, *Mya binghami*, *Pectunculus glycimeris*, *Aclis gulsonæ*, *Emarginula fissura*, *Fissurella græca**, *Eolis tricolor*, *Tritonia plebeia*, *Hero formosa*, *Styclopsis grossularia*, *Cynthia morio*, *Forbesella tessellata*, *Corella parallelogramma*, *Ciona intestinalis*, *Ascidia mentula*, *A. plebeia*, *A. venosa*, *A. virginea* and *A. scabra*; there were many others, some of which are referred to below in the special reports on work done.

On a Dredging Expedition.

We brought back the rarer forms to preserve, and the most striking and beautiful specimens to keep alive

* See also Mr. Leicester's list on p. 33.

in the tanks, some of which, gorgeous red starfishes, spotted sea-anemones, and long-legged crabs, were the delight of visitors to the Aquarium during the next week or two.



Red Starfish.

Notes on Work Done in the District.

As usual my companions and fellow-workers in the Committee have kindly supplied me with brief reports as to their work in their own respective groups of animals during the year. In most cases these are merely preliminary notices of work which will appear in their own future papers in our volumes of the Fauna or in L.M.B.C. Memoirs.

Mr. I. C. Thompson reports as follows:—

"As in previous years, Mr. Chadwick has forwarded to me for examination tow-net gatherings taken about Port Erin Bay throughout the year. In addition to these I have collected material during several visits to the Biological Station. In last year's Report mention was made of some shoals of rare species of Copepoda taken for the first time in the L.M.B.C. district. One of these, the species being *Corycæus anglicus*, appeared on the 29th of May, 1899. In the 18th Annual Report of the Fishery Board for Scotland, just published, Mr. Thomas Scott, F.L.S., reports that on the very same day, May 29th, this Copepod (which had not been recorded in Scottish Seas before or since 1896) was taken by tow-net in the Clyde in the vicinity of Ailsa Craig. The cause of the sudden migration of this southern species in quantity so far north is difficult to imagine. It has not been observed in our district, to my knowledge, during the present year. The general results of my examinations seem to indicate a remarkable sameness in the Plankton throughout the seasons of the year. During the early spring the nets yielded little but a profusion of Diatoms and Nauplii. The Cladocera, *Evadne nordmanni*, and *Podon intermedium* were the most conspicuous animals taken in early summer. Since then, with the exception of a single specimen of *Thaumaleus thompsonii*, Giesbrecht, new to the district, taken on September 8th, and another since, on November 18th, in Port Erin Bay, about half-a-dozen common species of Copepoda usually formed almost the entire bulk of the material obtained."

"In a paper by Mr. Andrew Scott and myself, published since the last Annual Report, we have given the following species new to the district, including one new to science:—*Ameira exilis*, T. and A Scott; *Delavalia mimica*, T.S.; *Laophonte denticornis*, T.S.; *Leptopsyllus intermedius*, T. and A.S.; *L. herdmani* (new species), I.C.T. and A.S.; *Lichomolgus hirsutipes*, T.S.; *Hersiliodes littoralis* (T.S.); *Caligus gurnardi*, Kroy.; *Chondracanthus radiatus*, Kroy; and *Nicothoe astaci*, Aud. and M. Edw."

Mr. Andrew Scott, from the Lancashire Sea Fish Hatchery, at Piel, sends me the following list of twenty additions to our fauna:—

TREMATODA.—*Octocotyle scombri* (Kuhn), on gills of Mackerel, Isle-of-Man. *Onchocotyle appendiculata* (Kuhn), on gills of *Raia batis*, off-shore stations.

CUMACEA.—*Eudorellopsis deformis* (Kroyer), on bottom, N.W. of Bahama Light Ship. *Pseudocuma similis*, G. O. Sars, on bottom, N.W. of Bahama Light Ship.

OSTRACODA.—*Cythere pellucida*, Baird, in shore pools, near Piel. *C. porcellaneæ*, Brady, in shore pools, near Piel. *C. gibbosa*, B. & R., in shore pools, near Piel.

BRANCHIURA.—*Argulus foliaceus* (Linn.), on trout from the Ribble, sent to University College for examination.

COPEPODA (free).—*Stephus gyrans* (Giesbrecht), amongst *Laminaria*, low tide Barrow channel. *Idya minor*, T. and A. Scott, amongst *Laminaria*, low tide Barrow channel.

COPEPODA (parasitic)—*Bomolochus soleæ*, Claus, in the nostrils of Cod, Barrow channel. *Caligus minimus*, Otto, inside the mouth of Bass, *Labrax lupus*, Barrow channel. *C. sp.***, inside the mouth of Gurnard, *Trigla gurnardus*, Barrow channel, **Pseudocaligus brevipedes* (B. Smith), inside the mouth of 3 bearded Rockling, *Onus tricirratus*, Barrow channel. *Lepeophtheirus pollachii*, B. Smith, on the tongue of Pollack, *Gadus pollachius*, off-shore stations. *Cyncus pallidus* (Van Beneden), on the gills of Conger, Barrow channel. *Chondracanthus cornutus* (Müller), on the gills of Flounder, Barrow channel. *C. clavatus*, B. Smith, on the gills of Lemon Sole, Barrow channel. *Charopinus dalmanni* (Retzius), in the spiracle of *R. batis* and *R. clavata*, off-shore stations. *Brachiella insidiosa*, Heller, on the gills of the Hake, off-shore stations.

Mr. Scott has started work on the worm parasites of fishes, and the two Trematodes recorded above are the first fruits of his labour. *Cythere pellucida* is the

* New genus. ** Apparently a new species.

Ostracod which he has selected as the subject of his L.M.B.C. Memoir. The new species and new genus of fish parasites under Copepoda will be described in a paper which Mr. Scott will lay before the Biological Society early next year, and which will contain notes on the other forms in this list.

Mr. Scott has finished the drawings for his L.M.B.C. Memoir on the parasitic Copepoda, *Lernœa branchialis* and *Lepeophtheirus pectoralis,* the latter being an external parasite on the flounder. He shows some interesting new stages in their life-history, and has come upon some important points concerning the injury such animals may cause to fishes when present in numbers.

Liverpool and the Isle of Man.

Miss L. R. Thornely has examined an enormous number of specimens of Hydroid Zoophytes, some dried and some preserved in spirit, obtained during the summer on dredging expeditions round Port Erin; and also many dead shells more or less covered with encrusting Polyzoa, with the following results :—

Off South end of Isle of Man, from 15 to 30 fathoms :—

HYDROID ZOOPHYTES.—*Hydrallmania falcata*, *Obelia geniculata*, *O. dichotoma*, *Halecium Beanii*, *H. tenellum*, *Diphasia rosacea* (beautiful colonies), *D. attenuata*, *Filellum serpens* (in large quantities on stems of *Sertularia abietina*, &c.), with among it "*Coppinia arcta*" of which Professor Nutting has recently given us the history.*

Calycella syringa, *Clytia johnstoni* (beautiful colonies with gonothecae), *Opercularella lacerata*, *Bougainvillia muscus*, *Bimeria vestita*, *Campanularia hincksii*, *C. volubilis*, *C. verticillata*, *Sertularia abietina*, *S. argentea*, *S. operculata* *Sertularella polyzonias*, *S. tenella*, *Lafoea dumosa*, *L. fruticosa*, *Eudendrium capillare*, *Antennularia ramosa*, *Plumularia catharina*, *P. setacea*, *Cuspidella costata*.

POLYZOA.—*Cellepora avicularis*, *C. costazii*, *C. dichotoma*, *Eucratea chelata*, *Bicellaria ciliata*, *Beania mirabilis*, *Scrupocellaria reptans*, *S. scruposa*, *Pedicellina cernua*, *P. gracilis*, *Crisia eburnea*, *C. denticulata*, *Membranipora pilosa*, *M. catenularia*, *Idmonea serpens*, *Cellaria fistulosa*, *Lichenopora hispida*, *Chorizopora brongniartii*, *Bowerbankia imbricata*, *Buskia nitens*, *Cylindroecium pusillum*, *Stomatopora johnstoni*, *Ætea recta*, *Æ. anguina*, *Porella concinna*, *Valkeria uva*.

The Zoophytes and Polyzoa of the preceding lists are in some cases crowded upon one another in wonderful profusion. On one piece of *Hydrallmania falcata*, 5 inches in height, were 14 other species belonging to 13 genera, and on one little piece of *Sertularia argentea* only two inches in height, were 12 other species representing no less than 12 genera, 5 of them Hydroids, and 7 Polyzoa.

* Hydroida from Alaska and Puget Sound, 1899, ending by establishing it, as not an independent hydroid species, but as the gonosome of species of Lafoeidae—in this case, therefore, probably, of *Filellum serpens*.

On dead shells (mostly *Pectunculus glycimeris*) trawled at 6 miles S.E. of of Calf Island, 30 fathoms, on September 13th, were found the following POLYZOA—

Schizoporella linearis, S. unicornis, S. auriculata, Mucronella peachii, M. ventricosa, M. variolosa, Hippothoa flagellum, Membranipora catenularia, M. flemingii, M. dumerilii, M. craticula, M. imbellis, M. pilosa, M. membranacea, Smittia reticulata, S. trispinosa, S. cheilostoma, Microporella ciliata, M. malusii, Diastopora obelia, D. suborbicularis, Stomatopora johnstoni, S. major, S. expansa, Lichenopora hispida, Chorizopora brongniartii, Aetea recta, Idmonea serpens, Flustra foliacea, Bugula avicularis, Cellepora avicularis, C. dichotoma, C. armata, Crisia ramosa, C. eburnea, Tubulipora lobulata.

Mr. A. O. WALKER sends me the following "Report on the Higher Crustacea from the Biological Station, Port Erin, received September 26th, 1900" :—

"The above were contained in four bottles, of which the two containing species new to the District were those from (1) the dredgings of September 13th, 1900, from 6 m. S.W. of Calf of Man, in 20 to 30 fathoms, and (2) from low tide at Calf of Man, on September 11th. Of the four species in the first bottle, two have not been previously recorded, viz., *Gnathia dentata*, Sars, two females, and one fine specimen of *Iphimedia eblanæ*, Bate. The former of these has not to my knowledge been previously recorded in British waters, and in spite of its agreeing exactly with G. O. Sars' excellent figure in the Isopoda of Norway, I have considerable hesitation in recording it in the absence of the male.

Among Professor Herdman's tow-nettings after dark in Port Erin Bay the only species calling for remark is *Schistomysis spiritus* (Norman), which has only been recorded before from Puffin Island. This night-gathering consisted chiefly of *Siriella norvegica* (Sars), mostly young; and *Macromysis inermis* (Rathke) among Schizopoda; and of *Apherusa bispinosa* (Bate) and *Paratylus swammerdamii* (M. Edw) among Amphipoda. The total number of species was 19. Of these six were Podophthalmata, one Cumacean, two Isopoda, and ten Amphipoda, all previously recorded.

A third bottle contained *Chelura terebrans*, Philippi, from the wooden piles of Ramsey Pier.

The fourth contained Amphipoda, &c., from Calf of Man, collected at low spring tide on September 11th. The most abundant species in this were *Stenothoe monoculoides* (Bate), and *Jassa (Podocerus) variegata* (Bate and Westwood). [See "Trans. L'pool Biological Society," Vol. IX., page 315.]

I retain the generic name *Jassa*, of Leach, 1815, in place of *Parajassa*, Stebbing, as I fail to see why it should be displaced by a genus of fossil fish founded in 1839. The bottle also contained several Idoteas too young to be identified with certainty, and a few specimens of *Janiropsis breviremis*, Sars. This species has not been previously recorded from Liverpool Bay, nor indeed from British waters, except a single female taken by me between tide marks in Valentia Harbour, Ireland. It is easily mistaken for young *Janira maculosa*, Leach, from which it may be distinguished by the different form of the operculum of the male and the much broader palp of the maxillipedes.

This bottle also contained five or six Pycnogonida, which Mr. G. H. Carpenter, who has kindly examined one, considers to be young specimens of *Anoplodactylus virescens* (Hodge). Two were still in the hexapod state, and a male had the false feet five-jointed as in *Phoxichilidium*, instead of six-jointed as in adult

Anoplodactylus, which Mr. G. H. Carpenter considers as a condition of immaturity. The auxiliary claws of the tarsi were rudimentary."

Bringing in the Dredge.

Mr. A. Leicester examined the Mollusca and dredge refuse obtained on our dredging expedition of September 13th. He reports to me that the best species found were :—

Six miles W.S.W. of Calf, 26 fathoms :—

Pecten testæ, P. tigrinus, Aclis gulsonæ, Eulima bilineata, Mya binghami, Lima elliptica, Rissoa striata, R. parva, R. reticulata, Odostomia spiralis, Cyclostrema nitens, C. serpuloides, Lepton nitidum, Modiolaria marmorata.

One mile S.E. of Calf Sound, 22 fathoms :—

Defrancia linearis, Lima loscombii, Cardium nodosum, Phasianella pullus, Trochus tumidus, Modiolaria marmorata.

Mr. L. St. George Byne and Mr. Leicester spent a considerable amount of time at Port Erin in studying the local Mollusca. I take the following passages from a letter written by Mr. Leicester :—"The most interesting discovery was perhaps *Lasæa rubra.* We have only found a few odd ones (dredged) until this occasion, when on the rocks near the Biological Station we found it in quantity inside old *Balanus* shells. We devoted some time to *Littorina rudis* and its varieties of which we took a good many, particularly var. *globosa*. Then the var. *elevata* of *Patella vulgata* is very abundant at Port St. Mary. We also took the var. *coerulea* at the Calf Sound. At Fleshwich we found *Patella athletica* and *Helcion lævis* in good numbers; but it is strange we could not find *Trochus helicinus*, and *Lacuna divaricata*, which I took there some years ago in quantity.

Messrs. Leicester and Byne have drawn up a paper on the Mollusca round the south end of the Isle-of-Man, which will probably be published soon.

In addition to the above reports, I may state that—

(1) Mr. T. S. Lea has continued on two occasions in mid-winter and mid-summer his interesting work in photographing marked areas of rock in the littoral zone in order to compare their condition from year to year and at different seasons. These faunistic photographs have been exhibited as lantern slides to the Biological Society by Mr. Lea.

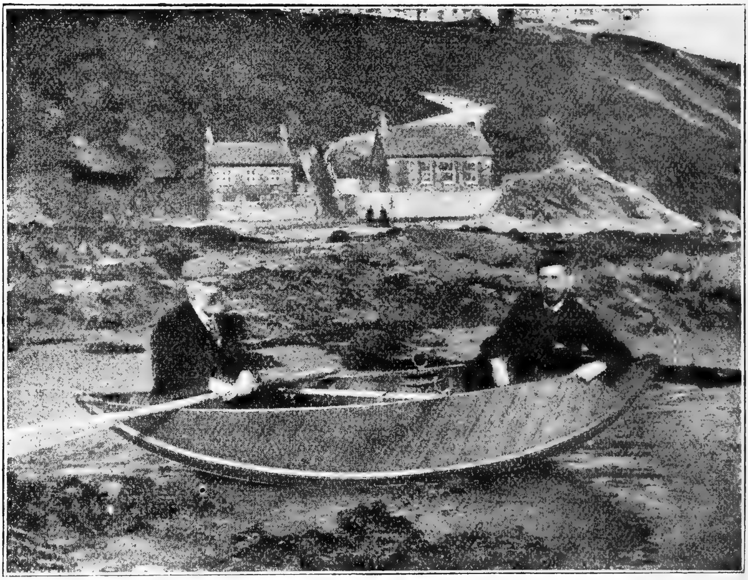
(2) Mr. F. J. Cole, during a month's work at Easter, continued his studies on the budding and growth of the colony in compound Ascidians commenced the previous year. He also devoted some time to the collection and preservation of material for his L.M.B.C. Memoir on *Sagitta*, the Arrow-worm. Now that we are specially looking for *Sagitta*, we find that it is remarkably variable in its appearances and disappearances, being sometimes very abundant everywhere (we have had a record lately of 90 specimens in one haul), and at other times apparently absent both in surface and bottom waters for days at a time. Sometimes it is to be found by sinking the tow-net when none are present on the surface, and during some night tow-nettings which I took in September I

found it was sometimes captured in the dark when we had failed to obtain any during the daytime. We also found in these night tow-nettings a few specimens of the closely allied genus *Spadella.*

(3) Mr. E. T. Browne, during a considerable stay in September and October, collected and studied the Medusæ of the Bay. He took regular tow-nettings, and made careful water-colour drawings of his material. Although the season was not a good one for Medusæ, and the hauls were often day after day disappointing, still Mr. Browne obtained some new forms and stages to figure, which will doubtless appear in his forthcoming work on the subject.

(4) Mr. H. Yates, of Manchester, has done some work on Polychæte worms; Mr. C. E. Jones, formerly of Liverpool, now moved to the Royal College of Science, South Kensington, studied sea-weeds in June; and on various visits I have collected and identified Tunicata of various kinds.

During the couple of weeks that I spent at Port Erin in September, disappointed in the scarcity of "plankton" during the day, and wishing to help Mr. Cole with material for his Memoir on *Sagitta*—the Arrow-worm—and remembering moreover the tremendous quantities obtained outside the bay in the bottom nets on a former occasion (in January, 1899), I went out in the Shellbend after dark, and took tow-nettings across the mouth of the bay. I did get a few more *Sagitta* by that method, but no great abundance; and I also got a few specimens of the curious allied form *Spadella.* But the most noteworthy result of these night tow-nettings was the greatly increased number of Crustacea obtained. Mr. A. O. Walker tells me of no less than nineteen different species of higher Crustacea in one of these hauls, several of them being rare forms. It is curious to notice how the difference between day and night affects some groups of animals in the sea and does not affect others. Mr. Browne tells me it makes no difference to his Medusæ. It certainly makes a marked difference in the Crustacea, which gives the night tow-netting a characteristic appearance.



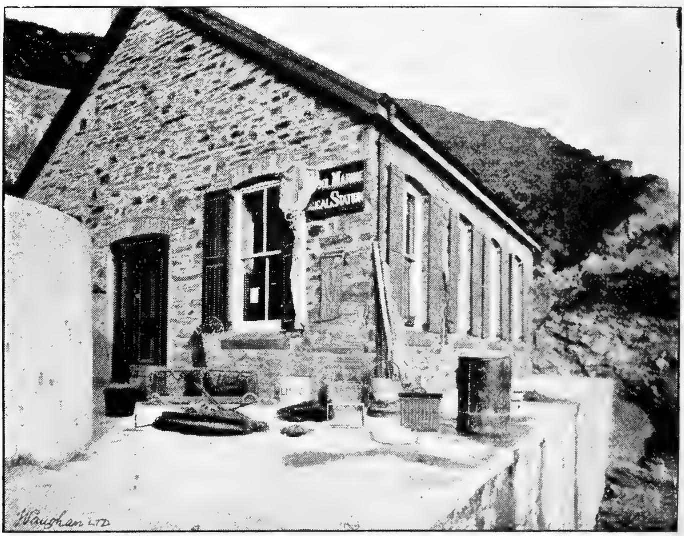
Our Shellbend Boat.

Scientific Meeting at Port Erin.

On Saturday, 15th September, 1900, the Isle-of-Man Natural History and Antiquarian Society held a meeting at Port Erin, in the Biological Station. The President, Dr. Richardson, the Secretary, Mr. P. M. C. Kermode, and a number of members of the Society attended. Our Committee was represented by the Hon. Treasurer, the Director, the Curator, and Mr. Kermode. Several workers in the Station at the time were present, and some of the people of Port Erin, so in all a good attendance was secured. The Society arrived about mid-day, and after luncheon at the Bellevue Hotel the party assembled in the Biological Station, where the Director, addressing the President, welcomed his party on behalf of the L.M.B.C., reminded them of the objects of the institution, and pointed out briefly the connection between the work carried out there and the investigation and conservation of the Manx fishing industries. The President then replied in the name of his Society, thanked the L.M.B.C. for their hospitality, and urged that the attention of the Insular Government should be drawn to the fact that the recommendation of the Industries Commission that a connection should be established between the Government and the Port Erin Biological Station had not yet been carried out. He then called upon Mr. Isaac C. Thompson, who had consented to deliver the address on this occasion. Mr. Thompson's subject was, "The Place of Copepoda in Nature."

The lecture proved of deep interest, and also conveyed—illustrated, as it was, by wall diagrams and by specimens under microscopes in the laboratory—a large amount of information as to the nature of the Copepoda, their place in the animal kingdom and their utility and importance to man. As reported in "Nature" (September 20th, p. 498), the lecturer "pointed out that the Copepoda are of the utmost value as scavengers, as they live on the products of decomposition, putrefaction, drainage matter, &c., and by their internal laboratories convert refuse matter into most valuable food material, some Copepoda constituting one of the chief sources of food for some fishes, and so of man. Mr. Thompson said that no less than 200 species have now been found in Liverpool Bay. Their beautiful organisation illustrates the truth that the wonderful structure of some animals which can only be studied with the microscope shows them to be as full of interest as those familiar to our ordinary vision. Besides the many free-swimming Copepods, there are also many species found as fish parasites, living on the gills and on other external parts of our common fishes; some of these are nourished by the fish and do harm, while others do not, their presence being probably rather an advantage than otherwise." Mr. Thompson was cordially thanked for his address, and then the formal meeting broke up, and the visitors were taken in parties round the laboratory and aquarium to see the animals in the tanks and the specimens under microscopes.

We were glad on this occasion to welcome to Port Erin the Rev. E. H. Kempson, the new Principal of King William College, who expressed a desire that the boys of the School might have some opportunities of visiting the Biological Station. That we readily arranged for, and a few weeks later Mr. Kempson brought over from



Outside of Biological Station.

Castletown a party consisting of Mr. Cartwright, the Science Master, and a set of boys. Our Curator took them round the Aquarium and Laboratory, and demonstrated specimens to them under the microscope. The meeting was, I believe, a success, and will probably be repeated.

On occasions like the meetings referred to above, and also on days when a number of visitors come together to the Aquarium, and it is obviously impossible for the Curator to explain the animals in each tank to every visitor, we have often felt the need of a short simply-worded printed description, giving the names and leading characteristics of the chief animals in the tanks. This has led to the decision that we should issue a short

Guide to the Aquarium.

Consequently I am now drawing up an account which will be appended to a future Report for the benefit of our subscribers and correspondents, and will be sold by the Curator to Aquarium visitors at the nominal price of one penny. The illustrations, which will form a useful and pleasing addition, are, for the most part, being prepared from careful drawings made by our Curator, Mr. Chadwick.

Distributional Charts.

(See Plates I. to VII.)

The idea of showing on charts the distribution of the various groups of animals in Port Erin Bay is one that has been before the Committee from the beginning. The practical carrying out of this idea was commenced by myself in 1885, when I spent five weeks in July and August in exploring the neighbourhood, and in making collections by dredging, tow-netting and shore work. I marked at that time all my species on a chart, but came to the conclusion in the end that it was still much too incomplete to publish, so in my paper entitled "Notes on the Marine Invertebrate Fauna of the Southern End of the Isle-of-Man," which appeared in the first volume of our "Fauna" in 1886, I contented myself with giving a sketch of the physical features of the neighbourhood, and of the special faunas of the different regions, and then entered opposite the species in the list such localities as "off Port Erin," "Shore Bay-ny-Carrickey," "off Spanish Head," "Shorepools Kitterland," &c. That list contained 316 species, the number of species we now have recorded from the south end of the Isle-of-Man is over 2,000.

Since the establishment of the Biological Station at Port Erin in 1893, the preparation of these distributional charts has engaged our attention from time to time, and several have been started but never completed. One prepared by Mr. J. H. Vanstone, when Curator, has hung for years on the back of the Laboratory door, and has been added to from time to time.

I have recently got Mr. Chadwick to bring together the work of his predecessors and of the members of the Committee, as recorded in our successive reports, and to express it in graphic form on the charts. I have added such additional records as I could from my own experience, and Mr. Thompson, Mr. Chadwick and I have carefully examined and criticised the result, as shown in Plates I.-VII. I may say that although we are confident of the substantial accuracy of all the records on these charts, we are painfully conscious of the many omissions, and of the incompleteness of the faunistic exposition. However, I have come to the conclusion that the only way of obtaining a more adequate record is to issue these incomplete charts in the belief that they will act as a stimulus, and that our students and specialists at the

Station during the next few seasons will take a salutary pride in demonstrating our omissions, and so gradually fill up the gaps in our present knowledge of the population of the sea-bottom.

We submit then for criticism and completion:—

1. A chart of the south-west corner of the Isle-of-Man, the wider area in which we often dredge from Port Erin in rowing and sailing boats. This extends from Fleshwich Bay on the north to Spanish Head on the south, and takes in the Calf Sound and the rich dredging ground off Bay Fine and Half-way Rock. This chart is on a smaller scale than those that follow, about 1½ inch to the mile. The numbers refer to the names of the species in the list given in the explanation of this Plate I.

2. A series of six charts of the more restricted area of Port Erin Bay, on a larger scale, about 7 inch to the mile. The first of these (Pl. II.) shows the Physical features, the soundings, and the nature of the bottom. In this, as well as in the following five charts, we have inserted the principal contours of depth, and also a series of magnetic north and south and east and west lines dividing the area into twenty squares, each measuring about 700 feet to the side. The positions of the lines are determined by prominent objects on the shore, which we believe will be easily recognised, and as the vertical and horizontal columns are lettered and numbered, we think that anyone with a little practice, when boating in the bay, will be able to determine in most cases what square he is in. The squares should be quoted by letter and numeral, and will soon become familiar to workers at the Station. For example, the Station itself lies opposite square A.2, the Traie Maenagh swimming bath is in A.1, the small boat jetty in B.3, and the buoy at the entrance to the bay is at the junction of four

squares. The remaining five charts (Plates III.-VII.) deal each with one or more groups of animals, and require no further explanation—each has an explanatory accompanying list (see p. 52).

A "Census" of the Sea.

I have referred above to these charts in connection with our "knowledge of the population of the sea-bottom." This work, so far as the L.M.B.C. is concerned, is an investigation in pure Zoology undertaken with no ulterior economic motives, but it is also clearly a first contribution towards that detailed investigation of the sea-bottom over the whole of the Irish Sea which I have recently pressed upon the attention of the Lancashire Sea-Fisheries Committee and of the Fisheries Department of the Board of Trade, as being at the present time of primary importance to us as a nation interested in great fishing industries. The Fishery Statistics collected and published at present by the Board of Trade are, I contend, inadequate. They do not give us the information we require. The system does not seem to be designed so as to realise and tackle the problem which ought to be tackled. What we must aim at ascertaining is not what a fisherman catches, but what there is for him to catch. We must in fact get series of accurate observations which will give us fair samples of the populations of the sea on the different grounds at the different seasons.

I have spoken of this in brief as aiming at taking an approximate "census" of the sea, but that, of course, is too ambitious a word, and indicates an exactness to which we probably could never hope to attain. Still the word serves to remind us of our approximate aim, and if we can even determine the numbers of a species on an area between wide limits, it will be of great importance. The investigation is, of course, beset with difficulties, but they are not insuperable. One great difficulty is to determine to what extent we can safely draw conclusions from our observations.

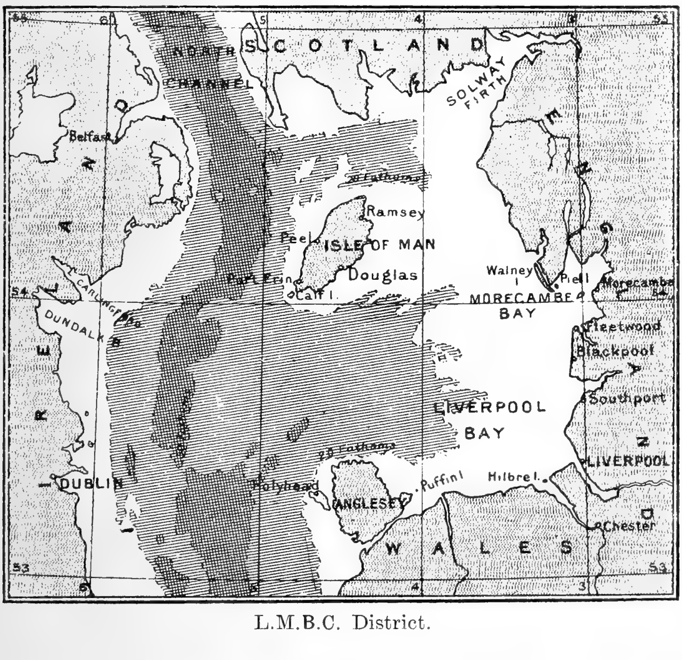
It may help to realise the problem if I take a homely illustration and liken the investigation to the case of an aeronaut in a balloon trawling along the streets of Liverpool through a thick fog. We may suppose that a drag in the neighbourhood of University College would yield some students—male and female—and a professor; one somewhere about the docks would doubtless capture some sailors, dock labourers, and a stevedore or two, while a lucky shot opposite the Town Hall might bring up a policeman, an electric car, and a couple of Aldermen. Now, if such experiences were repeated over and over again, would the conclusions that might naturally be drawn by the intelligent aeronaut as to the relations between organisms and environment in Liverpool be correct? The observed association of students with a professor, and of both with a college, would be justifiable. It would be correct to conclude that sailors, dock labourers and stevedores frequent the docks, and that Aldermen have some connection with a Town Hall; but the fact that electric cars are also abundant in front of the Town Hall is non-essential, and any conclusion such as that Aldermen and electric cars are usually associated with the same habitat, and are in any way inter-dependent, would be erroneous.

We can imagine many other cases of this kind where appearances might at first be deceptive, and false inferences might be drawn from observed facts. On the other hand, some true conclusions would be clearly indicated; and I do not doubt that it is much the same in our investigations as to the condition and population of the sea-bottom. It is probable, moreover, that the false inferences would be corrected by the accumulation of a greater number of statistics. It might be made out from further observations that electric cars are liable to become massed in various parts of the town, and have no necessary connection with Aldermen, and that policemen are widely but sporadically distributed. The more numerous our observations, the more our statistics accumulate, the less chance is there of erroneous conclusions.

My contention, then, is that such an investigation of our seas must be made, that it is urgent and should be made now, and that the Irish Sea is favourably situated and circumstanced at present to be made a test case before undertaking the much wider and still 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 who might be got to agree as to their regulations. It is a "self-contained" fish area, containing spawning banks, feeding grounds and "nurseries." It has several marine laboratories on its borders which would form centres for investigation, and it is controlled by two or three powerful Sea-Fisheries Committees, provided with excellent steamers, which might combine in the work. All that is required, beyond a carefully considered scheme of work, is authority from the Government to the local Committees to carry out such work, and a subsidy for say five years to meet the increased expense.

The Select Committee of the House of Commons, which considered the Undersized Fish Bill last summer, clearly recognised in their report the need of such a scheme of investigations, and they recommended that a Government Department should be equipped to carry it out. I am of opinion that the matter would be better entrusted, as I have indicated above, to the local Sea-Fisheries Committees.

In addition to the investigation of the bottom by dredging and trawling, the plankton in the surface and other waters would require periodic examination. We have discussed this fully during the past summer, both at Port Erin and Liverpool, and have had the advantage of hearing the opinion of Mr. E. T. Browne, who has had



L.M.B.C. District.

much experience of late years in plankton work. In order to get an adequate idea of the distribution of the minute floating organisms of our seas, we should certainly require to have weekly observations (or possibly even twice a week) taken, at both surface and bottom, at certain specified stations round the coast, of which we should recognise four as being necessary in the Irish Sea, and about 15 round the whole British Coast. We are willing to play our part in any such general scheme, but in the meantime we are going on with the work in our own district. Mr. Thompson, Mr. Scott, Mr. Chadwick and Mr. Ascroft are all at work, and we have drawn up and agreed upon a common list of pelagic organisms the occurrences of which in the various parts of our district will be periodically registered.

L.M.B.C. Memoirs and other Publications.

After a rather longer interval than usual the 5th volume of our "Fauna and Flora of Liverpool Bay" has been issued this winter. It contains reprints of the L.M.B.C. papers and reports since 1895, the date of publication of Vol. IV.

A new recruit to our band of workers, Mr. Herbert C. Robinson, who has recently joined the staff of the Zoological Department of University College as "Honorary Research Assistant," has undertaken to prepare for our "Fauna" a report upon the Marine Birds of the District. This will be ready for publication early in 1901, and Mr. Robinson has supplied me with the following note in regard to it:—

"Defining 'Sea and Shore Birds' in the most liberal sense, the L.M.B.C. area may be said to harbour some 80 to 100 species, of which, however, a very considerable proportion are of purely accidental occurrence. It is proposed to compile a list of those species which can in any sense be termed littoral or marine, which as far as is known have occurred in the district during the present century, whether as occasional visitors, on migration, or as residents. To each order will be prefixed a simple key, which it is hoped will render it possible to identify any species which is at all likely to be met with, whilst short descriptions of the various plumages and records of localities will be given under the head of each species. A bibliography of works bearing on the subject will be added in conclusion. From the nature of the subject the report can be nothing more than the merest compilation, but it is hoped that it may be of service as concentrating information which is at present somewhat scattered."

It will be remembered that the scheme of preparing and publishing a series of L.M.B.C. Memoirs on single marine animals or plants, written by specialists, was started about a year ago; and in last year's Report the issue of the first Memoir, that on Ascidia, was duly noticed. We also recorded there the kind donations of Mr. F. H. Gossage, which had made the publication of the Memoirs possible, and had met the expense of the preparation of good plates to illustrate the series. I am glad to be able now to announce that Mrs. Holt has lately sent me a cheque for £50, to be applied to the publication of further Memoirs. These kind gifts from both Mr. Gossage and Mrs. Holt have been a most effective help, and are appreciated by the Committee as a very welcome encouragement.

Four Memoirs have now been issued, of which three are Zoological and one Botanical, viz.:—

Memoir I. Ascidia, by Professor W. A. Herdman—published in October, 1899, with 60 pp. and five plates.

" II. Cardium, by Mr. James Johnstone—published in December, 1899, with 92 pp., six plates and a map.

" III. Echinus, by Mr. H. C. Chadwick—published in February, 1900, with 36 pp. and five plates.

" IV. Codium, by Professor Harvey Gibson and Miss H. P. Auld—published in April, 1900, with 26 pp. and three plates.

The next two Memoirs, No. V., ALCYONIUM, by Professor Hickson, and No. VI., on the Fish Parasites LERNÆA and LEPEOPHTHEIRUS, by Mr. Andrew Scott, are now in the printer's hands, and will be ready for distribution in a few weeks. LINEUS, by Mr. R. C. Punnett, will probably be out early in 1901. Others, such as the OYSTER, SAGITTA, and the PLAICE are in preparation.

In order to meet the wishes of the bookselling trade, the L.M.B.C. have decided to place the sale of their Memoirs in future in the hands of a well-known firm of scientific publishers, and they have made arrangements to this effect with Messrs. Williams & Norgate. This arrangement, however, is only in regard to the sale of the volumes, and does not relieve the L.M.B.C. of any responsibility either scientific or financial.

The production of the Memoirs will still take place in Liverpool, under the editorship and control of the officers of the Committee, Messrs. Williams & Norgate merely acting as agents for the distribution and sale of the books. Any of the other L.M.B.C. volumes or reports can also be obtained through Messrs. Williams & Norgate.

The complete list of the L.M.B.C. Memoirs published and in contemplation is now as follows:—

Memoir I. ASCIDIA, W. A. Herdman, 60 pp., 5 Pls.
II. CARDIUM, J. Johnstone, 92 pp., 7 Pls.
III. ECHINUS, H. C. Chadwick, 36 pp., 5 Pls.
IV. CODIUM, R. J. H. Gibson and Helen Auld.
V. ALCYONIUM, S. J. Hickson, 30 pp., 3 Pls.
VI. LERNÆA and LEPEOPHTHEIRUS, Andrew Scott.
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.
Gigartina, O. V. Darbishire.
Plaice, F. J. Cole and J. Johnstone.
Botrylloides, W. A. Herdman.
Cuttle-Fish (Eledone), W. E. Hoyle.
Ostracod (Cythere), Andrew Scott.
Patella, J. R. A. Davis and H. J. Fleure.
Calanus, I. C. Thompson.
Actinia, J. A. Clubb.
Bugula, Laura R. Thornely.
Hydroid, E. T. Browne.
Myxine, G. B. Howes.
Buccinum, M. F. Woodward.
Calcareous Sponge, R. Hanitsch.
Lineus, R. C. Punnett.
A Platyelminth, A. E. Shipley.
Sagitta, F. J. Cole.
Arenicola, J. H. Ashworth.
Antedon, H. C. Chadwick.
Oyster, W. A. Herdman and J. T. Jenkins.
Porpoise, A. M. Paterson.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Carcinus*, an Amphipod and a Pycnogonid (probably by A. R. Jackson).

Conclusion.

I think our Committee may claim that this is a favourable Report, and that it shows that there is a good deal of work being done upon a very small expenditure. And I have two remarks to make by way of conclusions drawn from a consideration of the year's work. The first is that our Treasurer wants more money. We are very grateful to our annual subscribers who give us our steady though restricted income, and so keep the Laboratory going, and also to kind friends like Mr. Gossage and Mrs. Holt, who have given us special larger donations to be applied to particular purposes. But if we had more money there is no doubt a great deal more work could be undertaken. We ought to have a larger Laboratory at Port Erin, a fish hatchery attached to it would be most useful, and a fund such as would enable us to make a freer use of boats and engage steam trawlers more frequently for expeditions would be a great advantage.

My second remark is that we want not only money but also *Men*. Personally I think more of men than of money. This L.M.B.C. work was started on the principles of co-operation and sub-division of labour, each man—and woman—cultivating his or her own little corner of the field, and there is still plenty of waste land to reclaim. We want new recruits, and especially young, active, enthusiastic recruits, and we can offer them the most delightful of pursuits—field work in Natural History. It is the most healthy, the most happy, the most engrossing and the most satisfying, physically, mentally and morally, of all occupations. Even taken merely as a hobby, it has been found by many busy professional and business men that the pursuit of some branch of Natural History adds a new pleasure to existence, gives them a constant interest in their open-air surroundings, lifts them above the petty cares and worries of the work-a-day life, and lets a little of the sunshine of Nature into their souls.

The subject of Marine Biology is as wide and as varied as the sea that environs it, and it bristles with problems of every description. The collector and classifier, the observer of habits, the investigator of life-histories, the morphologist studying structure, and the physiologist function, the bacteriologist and the chemicobiologist, the most transcendental evolutionist, and even the humble but necessary speciographer, whom it is the fashion now in some quarters to despise and deride, will all find in our local oceanography an ample field for their special researches. Here is work for many minds and many hands for many a year to come.

EXPLANATION OF THE PLATES.

Plate I.

Key to the Chart of the South-western corner of the Isle of Man.

FIG.

1. *Ascetta primordialis*, off Port Erin, 17 fms.
2. *Sycon ciliatum*, off Bay Fine, 18 fms, etc.
3. *Sycon asperum*, off Port Erin.
4. *Leucosolenia coriacea*, off Halfway Rock, 18 fms.
5. *Ute glabra*, one mile off Bradda Head, 15 fms.
6. *Leucandra gossei*, in caves near Sugar loaf Rock.
7. *Halichondria panicea*, off Bay Fine, etc.
8. *Pachymatisma johnstonia*, in caves near Sugar-loaf Rock.
9. *Stelleta collingsi*, in caves.
10. *Amphilectus incrustans*, in caves.
11. *Axinella stuposa*, off Port Erin, 15 to 20 fms.
12. *Suberites domuncula*, off Halfway Rock, 18 fms.
13. *Cliona celata*, off Bay Fine, 18 fms; a quarter mile W. of Fleshwick Bay, 13 fms; off Port Erin.
14. *Hydractinia echinata*, off Port Erin Breakwater, etc.
15. *Coryne vaginata*, on Fucus around Calf Island.
16. *Eudendrium ramosum*, off Port Erin, 10 to 20 fms.
17. *Eudendrium capillare* (?), on *Hyas coarctatus*, off Port Erin, 10 to 20 fms.
18. *Garveia nutans*, off Spanish Head, 15 fms.
19. *Tubularia indivisa*, on rocks around Calf Island and in caves.
20. *Tubularia simplex* (?), off Spanish Head, 15 fms.
21. *Clytia johnstoni*, off Bradda Head, 15 fms.
22. *Obelia flabellata*, off Port Erin, 10 to 20 fms.
23. *Obelia dichotoma*, off Port Erin, 10 to 20 fms.

FIG.

24. *Campanularia volubilis*, off Spanish Head.
25. *Campanularia verticillata*, off Bay Fine, 18 fms.
26. *Campanularia hincksii*, off Spanish Head.
27. *Campanularia caliculata*, off Port Erin, 10 to 20 fms.
28. *Campanularia angulata*, off Port Erin, 10 to 20 fms.
29. *Campanularia flexuosa*, off Port Erin, 10 to 20 fms.
30. *Campanularia neglecta*, off Port Erin, 10 to 20 fms.
31. *Gonothyrea lovéni*, off Port Erin, 10 to 20 fms.; off Bay Fine, 18 fms.
32. *Lafoëa dumosa*, off Bay Fine, 18 fms.; off Spanish Head, 10 to 20 fms.
33. *Calycella syringa*, off Port Erin, 10 to 20 fms.
34. *Coppinia arcta*, off Spanish Head.
35. *Halecium halecinum*, off Port Erin, Bay Fine, and Spanish Head, 10 to 20 fms.
36. *Halecium beanii*, off Bay Fine, 15 to 18 fms.; off Spanish Head.
37. *Sertularella polyzonias*, off Port Erin and Bay Fine.
38. *Sertularella rugosa*, off Bradda Head, 15 fms.
39. *Diphasia rosacea*, off Port Erin, 10 to 20 fms.
40. *Sertularia abietina*, off Spanish Head, N. side of Calf Island and Bay Fine.
41. *Sertularia operculata*, off Spanish Head.
42. *Sertularia filicula*, off Port Erin, 10 to 20 fms.
43. *Sertularia argentea*, off Port Erin, 10 to 20 fms.
44. *Hydrallmania falcata*, off Spanish Head, etc.
45. *Antennularia ramosa*, off Port Erin, 10 to 20 fms.; off Bradda Head and Halfway Rock.
46. *Antennularia antennina*, off Spanish Head and Bay Fine, 18 fms.
47. *Aglaophenia pluma*, off Bradda Head.
48. *Aglaophenia myriophyllum*, off Halfway Rock and Bay Fine, 15 fms.
49. *Plumularia catharina*, off Halfway Rock.

FIG.

50. *Plumularia pinnata,* off Bradda Head.

51. *Sagartia nivea,* off Halfway Rock and on Calf Island.

51A. *Sagartia venusta,* on Clets and Calf Island.

51B. *Sagartia miniata,* on Clets and Calf Island.

52. *Corynactis viridis,* off Port Erin Breakwater, and Spanish Head.

53. *Epizoanthus* (*Polythoa*) *arenacea,* off Spanish Head.

54. *Adamsia palliata,* off Port Erin Breakwater, Bay Fine, and Spanish Head.

55. *Urticina* (*Tealia*) *crassicornis,* generally distributed on rocky ground.

56. *Alcyonium digitatum,* on Port Erin Breakwater, and off Spanish Head.

57. *Sarcodictyon catenata,* off Bay Fine, Port Erin, and Spanish Head.

58. *Asterias rubens,* off Bradda Head, Bay Fine, etc.

59. *Asterias glacialis,* N. of Calf Island, 14 fms.

60. *Henricia sanguinolenta,* off Port Erin, Halfway Rock and Aldrick.

61. *Stichaster roseus,* off N. corner of Calf Island, 17 fms.

62. *Solaster endeca,* off Bay Fine and Halfway Rock.

63. *Solaster papposus,* off Bradda Head, Bay Fine, and Kitterland.

64. *Palmipes placenta,* off Halfway Rock, 18 fms.

65. *Porania pulvillus,* off Bay Fine, 18 fms, and N. of Calf Sound.

66. *Astropecten irregularis,* off Bradda Head.

67. *Ophiura ciliaris,* off Port Erin Breakwater, Bay Fine, and Aldrick.

68. *Ophiura albida,* off Port Erin, Bay Fine, and Aldrick.

69. *Amphiura elegans,* off Port Erin Breakwater, and Bay Fine.

70. *Ophiopholis aculeata,* off Port Erin, 12 fms.

71 *Ophiocoma nigra,* off Bay Fine and Aldrick.

FIG.

72. *Ophiothrix pentaphyllum*, off Bay Fine, Aldrick, Spanish Head, etc.
73. *Ocnus brunneus*, off Port Erin and Spanish Head.
74. *Thyone papillosa*, off Castles, Port Erin, 15 fms.
75. *Thyone fusus*, off Port Erin, 20 fms.
76. *Thyone raphanus*, off Port Erin, 20 fms.
77. *Cucumaria hyndmanni*, off Port Erin, 20 fms.
78. *Echinus esculentus*, generally distributed on rocky ground.
79. *Echinus miliaris*, off Port Erin Breakwater, and Bay Fine.
80. *Echinocyamus pusillus*, off Bay Fine, Aldrick and Halfway Rock.
81. *Spatangus purpureus*, off Port Erin, 15 fms, and off Aldrick, 18 fms.
82. *Echinocardium flavescens*, one mile off Bradda Head, 15 fms.
83. *Antedon bifida* (=*rosacea*), off Castles, Port Erin, and off Bay Fine, 18 fms.
84. *Lineus longissimus*, off N. Corner of Calf Island, 17 fms.
85. *Amphiporus pulcher*, off Port Erin, Bay Fine, Aldrick, etc.
86. *Micrura fasciolata*, off Halfway Rock, 18 fms.
87. *Micrura candida*, N. of Halfway Rock, 15 fms.
88. *Carinella aragoi*, N. of Halfway Rock, 15 to 18 fms.
89. *Cephalothrix bioculata*, off Port Erin, 15 fms.
90. *Tetrastemma melanocephalum*, off Port Erin, 15 to 20 fms.
91. *Tetrastemma robertianæ*, off Port Erin, 15 fms.
92. *Prosorhochmus claparedii*, N. of Halfway Rock, 15 fms.
93. *Cerebratulus fuscus*, off Port Erin, 15 to 20 fms.
94. *Polygordius sp.*, off Bradda Head.
95. *Hermione hystrix*, off Port Erin, Halfway Rock, and Spanish Head.

FIG.

96. *Aphrodita aculeata*, N. of Calf Island.
97. *Polynoe squamata*, off Port Erin and Spanish Head.
98. *Polynoe haliæti*, off Port Erin, 15 fms.
99. *Halosydna gelatinosa*, off Aldrick and Bay Fine, 15 to 20 fms.
100. *Hermadion assimile*, on Echinus, off Port Erin and Bay Fine.
101. *Sthenelais zetlandica*, off Port Erin, 20 fms.
102. *Chætopterus variopedatus*, N. of Calf Island.
103. *Pectinaria belgica*, off Port Erin, 20 fms.
104. *Terebella nebulosa*, off Port Erin, 10 to 20 fms.
105. *Serpula vermicularis*, off Port Erin, Spanish Head, etc.
106. *Serpula triqueter*, off Halfway Rock, 18 fms.
107. *Filograna implexa*, off Bradda Head, Bay Fine, etc.
108. *Ætea truncata*, off Port Erin, 10 to 15 fms.
109. *Ætea recta*, off Halfway Rock.
110. *Gemellaria loricata*, off Port Erin and Bay Fine.
111. *Eucratea chelata*, off Port Erin.
112. *Scrupocellaria scrupea*, off Halfway Rock.
113. *Canda (Scrupocellaria) reptans*, off Port Erin, Halfway Rock, etc.
114. *Bicellaria ciliata*, off Bay Fine.
115. *Bugula turbinata*, off Bay Fine.
116. *Bugula flabellata*, off Bradda Head.
117. *Bugula plumosa*, off Port Erin.
118. *Bugula calathus*, off Bradda Head.
119. *Beania mirabilis*, off Port Erin, 5 to 10 fms.
120. *Cellaria fistulosa*, off Bay Fine and Halfway Rock.
121. *Flustra foliacea*, off Port Erin.
122. *Membranipora pilosa*, generally distributed.
123. *Membranipora catenularia*, off Port Erin.
124. *Membranipora craticula*, off Port Erin and Halfway Rock.

FIG.

125. *Membranipora flemingii*, off Port Erin and Halfway Rock.
126. *Membranipora dumerillii*, off Port Erin and Halfway Rock.
127. *Membranipora imbellis*, off Port Erin and Halfway Rock.
128. *Cribrilina punctata*, off Spanish Head.
129. *Membraniporella nitida*, off Spanish Head.
130. *Microporella malusii*, off Port Erin and Halfway Rock.
131. *Microporella ciliata*, off Port Erin and Halfway Rock.
132. *Chorizopora brongniartii*, off Port Erin and Halfway Rock.
133. *Schizoporella linearis*, off Port Erin and Halfway Rock.
134. *Schizoporella spinifera*, off Port Erin.
135. *Schizotheca fissa*, off Port Erin and Halfway Rock.
136. *Hippothoa divaricata*, off Port Erin and Halfway Rock.
137. *Hippothoa distans*, off Port Erin and Halfway Rock.
138. *Lepralia edax*, N. of Kitterland, 18 fms.
139. *Porella concinna*, off Port Erin and Halfway Rock.
140. *Smittia trispinosa*, off Port Erin and Halfway Rock.
141. *Smittia reticulata*, off Port Erin and Halfway Rock.
142. *Mucronella peachii*, off Port Erin and Halfway Rock.
143. *Mucronella ventricosa*, off Port Erin and Halfway Rock.
144. *Mucronella coccinea*, off Port Erin and Halfway Rock.
145. *Cellepora pumicosa*, off Port Erin and Halfway Rock.
146. *Cellepora costazii*, off Port Erin and Halfway Rock.

146A. *Cellepora dichotoma*, off Port Erin and Halfway Rock.

147. *Crisia cornuta*, off Port Erin and Halfway Rock.
148. *Crisia eburnea*, off Spanish Head and Bay Fine.
149. *Crisia ramosa*, off Port Erin and Halfway Rock.
150. *Stomatopora johnstoni*, off Port Erin and Halfway Rock.

FIG.

151. *Tubulipora flabellaris,* off Port Erin and Halfway Rock.

152. *Idmonea serpens,* off Halfway Rock.

153. *Diastopora suborbicularis,* off Port Erin and Halfway Rock.

154. *Diastopora patina,* off Port Erin, Halfway Rock, and Spanish Head.

155. *Diastopora obelia,* off Port Erin and Halfway Rock.

156. *Lichenopora hispida,* off Spanish Head.

157. *Alcyonidium gelatinosum,* off Port Erin.

158. *Alcyonidium mytili,* off Port Erin and Halfway Rock.

159. *Alcyonidium hirsutum,* off Port Erin.

160. *Amathia lendigera,* off Castles, Port Erin, 12 fms.

161. *Bowerbankia pustulosa,* off Port Erin, 10 to 15 fms.

162. *Cylindrœcium dilatatum,* off Port Erin, 10 to 15 fms.

163. *Mimosella gracilis,* off Bay Fine.

164. *Pedicellina cernua,* off Bradda Head and Bay Fine.

165. *Cancer pagurus,* generally distributed on rocky ground.

166. *Xantho tuberculata,* off Halfway Rock.

167. *Carcinus mœnas,* generally distributed in shallow water.

168. *Portunus pusillus,* outside Port Erin breakwater and off Bay Fine.

169. *Portunus arcuatus,* ¼ mile off shore, W. of Fleshwick Bay.

170. *Portunus puber,* outside Breakwater, and off Bay Fine.

171. *Pinnotheres veterum,* off Aldrick.

172. *Macropodia (Stenorhynchus) rostrata,* generally distributed.

173. *Inachus dorsettensis,* ¾ mile N. of Kitterland, 18 fms.

174. *Hyas araneus,* generally distributed in shallow water.

175. *Hyas coarctatus,* generally distributed in shallow water.

FIG.

176. *Pisa biaculeata*, off Port Erin.
177. *Eurynome aspera*, off Bay Fine, Aldrick, and Spanish Head.
178. *Ebalia tuberosa*, off Port Erin and Bay Fine.
179. *Ebalia cranchii*, off Port Erin, and N. of Kitterland.
180. *Ebalia tumefacta*, off Spanish Head.
181. *Eupagurus bernhardus*, generally distributed.
182. *Eupagurus prideaux*, off Port Erin Breakwater, Bay Fine, and Spanish Head.
183. *Eupagurus cuanensis*, off Halfway Rock, 18 fms.
184. *Porcellana longicornis*, off Bay Fine and Aldrick.
185. *Galathea intermedia*, generally distributed.
186. *Galathea dispersa*, off Halfway Rock, 18 fms.
187. *Galathea nexa*, off Bay Fine and Aldrick.
188. *Palinurus vulgaris*, off Calf Island.
189. *Astacus gammarus* (*Homarus vulgaris*), generally distributed on rocky ground.
190. *Crangon vulgaris*, off Port Erin.
191. *Crangon trispinosus*, off Breakwater and Bay Fine.
192. *Crangon allmani*, off Halfway Rock, 18 fms.
193. *Crangon fasciatus*, outside Breakwater, Port Erin.
194. *Hippolyte varians*, generally distributed.
195. *Spirontocaris spinus*, off Bay Fine.
196. *Pandalus annulicornis*, generally distributed.
197. *Idotea marina*, generally distributed.
198. *Astacilla longicornis*, off Bay Fine.
199. *Pleurocrypta intermedia*, on *Galathea intermedia*, off Bay Fine.
200. *Ampelisca macrocephala*, off Port Erin, 10 to 20 fms.
201. *Leucothoe spinicarpa*, off Port Erin.
202. *Eusirus longipes*, off Port Erin, 10 to 20 fms.
203. *Balanus balanoides*, generally distributed on rocks between tide marks.

FIG.

204. *Scalpellum vulgare*, on *Antennularia ramosa*, off Bay Fine.

205. *Pallene brevirostris*, off Spanish Head.

206. *Phoxichilidium femoratum*, off Port Erin.

207. *Pephredo hirsuta* (?), off Port Erin, 15 fms.

208. *Phoxichilus spinosus*, off Port Erin, 15 fms.

209. *Pycnogonum littorale*, off Halfway Rock, 18 fms, and Aldrick.

210. *Anomia ephippium*, generally distributed.

211. *Ostrea edulis*, off Halfway Rock, 18 fms.

212. *Pecten varius*, off Bay Fine and Aldrick.

213. *Pecten opercularis*, off Bradda Head and Aldrick.

214. *Pecten tigrinus*, off Bay Fine and Aldrick.

215. *Pecten pusio*, off Halfway Rock.

216. *Pecten maximus*, off Aldrick and Calf Island.

217. *Lima loscombii*, off Spanish Head and Bay Fine.

218. *Lima elliptica*, off Spanish Head.

219. *Mytilus modiolus*, off Calf Island and Spanish Head.

220. *Modiolaria marmorata*, off Spanish Head.

221. *Nucula nucleus*, off Bradda Head and Spanish Head.

222. *Pectunculus glycimeris*, off Bay Fine, Aldrick, etc.

223. *Arca tetragona*, off Spanish Head.

224. *Lepton sp.*, off Kitterland.

225. *Cardium echinatum*, off Port Erin.

226. *Cardium norvegicum*, off Port Erin and Bay Fine; dead but fresh.

227. *Cyprina islandica*, off Bay Fine and Kitterland; dead but fresh.

228. *Astarte sulcata*, off Port Erin, 10 to 20 fms.

229. *Venus exoleta*, off Port Erin and Bay Fine.

230. *Venus lincta*, off Breakwater and Bay Fine; dead but fresh.

231. *Venus casina*, off Port Erin and Halfway Rock.

232. *Tapes virgineus*, off Bay Fine and Spanish Head.

FIG.

233. *Tellina balthica*, off Port Erin.
234. *Psammobia tellinella*, off Spanish Head.
235. *Mactra solida*, off Port Erin.
236. *Pandora inæquivalvis*, off Bay Fine.
237. *Thracia prætenuis*, off Port Erin.
238. *Mya truncata*, off Bay Fine.
239. *Saxicava rugosa*, off Bay Fine and Aldrick.
240. *Dentalium entale*, off Bradda Head and Spanish Head, 20 fms.
241. *Chiton cancellatus*, off Port Erin.
242. *Chiton cinereus*, off Bay Fine and Spanish Head.
243. *Emarginula fissura*, off Port Erin and Spanish Head.
244. *Fissurella græca*, off Port Erin and Spanish Head.
245. *Capulus hungaricus*, off Bay Fine.
246. *Cyclostrema nitens*, off Kitterland.
247. *Trochus zizyphinus*, off Port Erin, Bay Fine, etc.
248. *Trochus magus*, off Port Erin and Aldrick.
249. *Trochus millegranus*, off Halfway Rock.
250. *Phasianella pullus*, off Breakwater, Port Erin.
251. *Odostomia nitidissima*, off Kitterland.
252. *Odostomia acicula*, off Kitterland.
253. *Odostomia rufa*, off Breakwater, Port Erin.
254. *Eulima bilineata*, off Kitterland.
255. *Natica catena*, off Spanish Head.
256. *Natica alderi*, off Bay Fine and Spanish Head.
257. *Velutina lævigata*, off Bay Fine.
258. *Aporrhaïs pes-pelicani*, off Port Erin and Aldrick.
259. *Buccinum undatum*, generally distributed.
260. *Murex erinaceus*, off Bay Fine, Aldrick, and Spanish Head.
261. *Trophon muricatus*, off Port Erin.
262. *Fusus gracilis*, off Spanish Head.
263. *Fusus antiquus*, off Spanish Head.
264. *Pleurotoma nebula*, off Port Erin.

FIG.

265. *Pleurotoma turricola*, off Spanish Head.
266. *Cypræa europæa*, off Port Erin and Aldrick.
267. *Actæon tornatilis*, off Castles, Port Erin.
268. *Bulla hydatis*, off Castles and Bay Fine.
269. *Scaphander lignarius*, off Bay Fine.
270. *Aplysia punctata*, generally distributed.
271. *Pleurobranchus membranaceus*, off Spanish Head.
272. *Goniodoris castanea*, off Spanish Head.
273. *Triopa claviger*, off Bay Fine.
274. *Polycera quadrilineata*, off Breakwater and Bay Fine.
275. *Dendronotus arborescens*, off Spanish Head.
276. *Hero formosa*, off Bay Fine.
277. *Doto coronata*, off Breakwater and Bay Fine.
278. *Doto pinnatifida*, off Bay Fine.
279. *Doto fragilis*, off Port Erin and Spanish Head.
280. *Facelina drummondi*, off Breakwater, Port Erin.
281. *Coryphella lineata*, off Port Erin, 10 fms.
282. *Cratena amœna*, off Halfway Rock.
283. *Galvina picta*, off Port Erin.
284. *Galvina farrani*, off Breakwater, Port Erin.
285. *Galvina tricolor*, off Breakwater and Spanish Head.
286. *Runcina coronata*, off Bay Fine.
287. *Actæonia corrugata*, off Bay Fine.
288. *Limapontia nigra*, off Bay Fine.
289. *Melampus bidentatus*, off Bay Fine.
290. *Botrylloides rubrum*, off Spanish Head.
291. *Morchellium argus*, off Bay Fine, Halfway Rock, etc.
292. *Leptoclinum asperum*, off Port Erin.
293. *Leptoclinum durum*, off Breakwater, Port Erin.
294. *Clavelina lepadiformis*, off Castles, Bay Fine, and Spanish Head.
295. *Perophora listeri*, off Bay Fine and Spanish Head.
296. *Ciona intestinalis*, generally distributed.
297. *Ascidiella virginea*, off Port Erin, 10 fms.

FIG.

298. *Ascidiella scabra,* off Port Erin, 10 fms.
299. *Ascidiella venosa,* off Aldrick.
300. *Ascidiella aspersa,* off Breakwater, Bay Fine, etc.
301. *Ascidia mentula,* off Bay Fine and Halfway Rock.
302. *Ascidia plebeia,* off Spanish Head, 20 fms.
303. *Corella parallelogramma,* off Castles, Bay Fine, and Spanish Head.
304. *Styelopsis grossularia,* off Port Erin and Spanish Head.
305. *Polycarpa comata,* off Halfway Rock.
306. *Polycarpa pomaria,* off Bay Fine, 12 fms.
307. *Polycarpa glomerata,* in caves.
308. *Polycarpa monensis,* off Port Erin, 15 fms.
309. *Cynthia morus,* off Halfway Rock and Bay Fine.
310. *Molgula occulta,* off Bradda Head and Spanish Head.
311. *Eugyra glutinans,* off Halfway Rock and Spanish Head.

Plate II.

This Chart shows the physical features, soundings, and bottoms in Port Erin Bay, and is explained on page 41.

Plate III.

Key to the Chart, showing the distribution of the Porifera, Coelentera, and Echinoderma.

FIG.

1. *Leucosolenia coriacea,* in coralline pools, and at Fleshwick.
2. *Leucosolenia botryoides,* in Pat's Dub and other coralline pools, and at Fleshwick.
3. *Sycon compressum,* in coralline pools and under stones, and at Fleshwick.
4. *Sycon coronatum,* in coralline pools and under stones, and at Fleshwick.

FIG.

5. *Leucandra gossei*, under stones at extreme low water, and at Fleshwick.
6. *Leucandra fistulosa*, under stones at extreme low water, and at Fleshwick.
7. *Leucandra johnstoni*, under stones at extreme low water, and at Fleshwick.
8. *Leucandra nivea*, under stones and on boulders, and at Fleshwick.
9. *Halisarca dujardini*, in coralline pools.
10. *Halichondria panicea*, under stones and on rocks, and at Fleshwick.
11. *Reniera elegans*, in coralline pools.
12. *Reniera densa*, in coralline pools.
13. *Amphilectus incrustans*, on boulders at extreme low water.
14. *Myxilla* (*Halichondria*) *irregularis*, under stones at extreme low water.
15. *Hymeniacidon caruncula*, on rocks and boulders.
16. *Hymeniacidon sanguineum*, on rocks and boulders.
17. *Clava multicornis*, on *Fucus*, and in coralline pools.
18. *Hydractinia echinata*, on shell of *Buccinum* inhabited by *Eupagurus*.
19. *Coryne vaginata*, under ledges of rock at low water.
20. *Tubularia larynx*, under stones and on Breakwater.
21. *Clytia johnstoni*, on *Chorda filum*.
22. *Obelia geniculata*, on *Chorda filum* and *Laminaria*.
23. *Campanulina repens*, in rock pool.
24. *Coppinia arcta*.
25. *Sertularia pumila*, under ledges of rock at low water.
26. *Antennularia antennina*, off Bradda Head.
27. *Antennularia ramosa*, off Bradda Head.
28. *Plumularia echinulata*, in coralline pools.
29. *Alcyonium digitatum*, on Breakwater.
30. *Sarcodictyon catenata*, off Breakwater.

FIG.

31. *Corynactis viridis*, in rock pools and off Breakwater.
32. *Halcampa crysanthellum*, in sand at low water.
33. *Metridium* (*Actinoloba*) *dianthus*, on Breakwater.
34. *Sagartia bellis*, in coralline pools.
35. *Sagartia venusta*, in crevices of rock at extreme low water.
36. *Sagartia miniata*, in crevices of rock at extreme low water.
37. *Adamsia palliata*, on shell inhabited by *Eupagurus prideaux*.
38. *Actinia equina*, common on rocks between tide marks.
39. *Anemonia sulcata*, common in pools and at low water.
40. *Urticina* (=*Tealia*) *crassicornis*, common at low water.
41. *Bunodes verrucosa* (*gemmacea*), common in pools and crevices at low water.
42. *Asterias rubens*, at and below low water mark, common.
43. *Henricia sanguinolenta*, amongst roots of *Laminaria* and outside Breakwater.
44. *Solaster papposus*, outside Breakwater, rare at low water.
45. *Astropecten irregularis*, off the Sker.
46. *Asterina gibbosa*, in coralline pools.
47. *Echinus esculentus*, common at and below low water.
48. *Echinus miliaris*, at low water on S. side of bay.
49. *Echinocardium cordatum*, in sand.
50. *Spatangus purpureus*, off Castles.
51. *Echinocyamus pusillus*, off the buoy.
52. *Synapta inhærens*, in sand and muddy gravel.
53. *Cucumaria hyndmani*, under stones at extreme low water, rare.
54. *Ophiura ciliaris*, across mouth of bay.
55. *Ophiura albida*, across mouth of bay.
56. *Ophiopholis aculeata*, under stones at low water.

E

FIG.

57. *Amphiura elegans*, in coralline pools and under stones.
58. *Ophiothrix pentaphyllum*, common under stones at low water.
59. *Ophiocoma nigra*, off Castles.
60. *Antedon bifida* (=*rosacea*), outside Breakwater.

Plate IV.

Key to the Chart showing the distribution of the Turbellaria, Nemertea, and Chætopoda.

FIG.

1. *Aphanostoma diversicolor*, in rock pools.
2. *Convoluta paradoxa*, in rock pools.
3. *Convoluta flavibacillum*, in rock pools.
4. *Promesostoma marmoratum*, in rock pools.
5. *Promesostoma ovoideum*, in shell débris.
6. *Promesostoma lenticulatum*, in rock pools.
7. *Byrsophlebs intermedia*, in rock pools.
8. *Proxenetes flabellifer*, in rock pools.
9. *Pseudorhynchus bifidus*, among drift weed.
10. *Acrorhynchus caledonicus*, among sea-weeds.
11. *Macrorhynchus naegelii*, in rock pools.
12. *Macrorhynchus helgolandicus*, in rock pools.
13. *Hyporhynchus armatus*, 15 fms, outside Breakwater.
14. *Provortex balticus*, in rock pools.
15. *Plagiostoma sulphureum*, in rock pools.
16. *Plagiostoma vittatum*, in rock pools.
17. *Vorticeros auriculatum*, in rock pools.
18. *Allostoma pallidum*, in rock pools.
19. *Cylindrostoma quadrioculatum*, in rock pools.
20. *Cylindrostoma inerme*, among drift weed.
21. *Monotus lineatus*, in rock pools.
22. *Monotus fuscus*, among *Balanus*, on rocks.
23. *Leptoplana tremellaris*, under stones.
24. *Cycloporus papillosus*, under stones and off Bradda Head.

FIG.

25. *Oligocladus sanguinolentus*, among shell débris outside Breakwater.
26. *Stylostomum variabile*, among shell débris outside Breakwater.
27. *Carinella aragoi*, under stones at low water.
28. *Cephalothrix bioculata*, under stones.
29. *Amphiporus pulcher*, in shell débris outside Breakwater.
30. *Amphiporus lactifloreus*, under stones.
31. *Amphiporus dissimulans* in shell débris outside Breakwater.
32. *Tetrastemma flavidum*, on weeds and in pools.
33. *Tetrastemma dorsale*, under stones.
34. *Tetrastemma nigrum*, among weeds.
35. *Tetrastemma candidum*, among weeds.
36. *Tetrastemma melanocephalum*, among weeds.
37. *Tetrastemma robertianæ*, on shelly ground in 15 fms.
38. *Nemertes neesii*, common between tide marks.
39. *Lineus obscurus*, common between tide marks.
40. *Lineus longissimus*, under stones.
41. *Micrura fasciolata*, on shelly ground.
42. *Cerebratulus*, sp. in sand.
43. *Dinophilus tæniatus*, in rock pools.
44. *Polygordius*, sp., off Bradda.
45. *Clitellio arenarius*, under stones.
46. *Polynoë imbricata*, under stones.
47. *Polynoë reticulata*, under stones.
48. *Hermadion assimile*, on *Echinus*.
49. *Sthenelais boa*, under stones.
50. *Nephthys cæca*, in sand.
51. *Nephthys hombergi*, in sand.
52. *Eulalia viridis*, on Breakwater.
53. *Phyllodoce maculata*, under stones.
54. *Phyllodoce laminosa*, under stones.

FIG.

55. *Nereis pelagica*, under stones.
56. *Nereis fucata*, commensal with *Eupagurus*.
57. *Syllis armillaris?* in rock pools.
58. *Nerine vulgaris*, in sand.
59. *Arenicola marina*, in sand.
60. *Arenicola ecaudata*, under stones.
61. *Arenicola grubii*, under stones.
62. *Capitella capitata*, under stones.
63. *Owenia filiformis*, in sand.
64. *Cirratulus tentaculatus*, under stones.
65. *Amphitrite figulus*, under stones.
66. *Lanice conchilega*, in sand.
67. *Amphiglena mediterranea*, in rock pools.
68. *Pomatoceros triqueter*, on stone and dead shells.
69. *Spirorbis borealis*, on *Fucus* everywhere.
70. *Filograna implexa*, on stones and dead shells.

Plate V.

Key to the Chart showing the distribution of the Crustacea.

FIG.

1. *Cancer pagurus*, small, under stones, and adult off Bradda Head.
2. *Pilumnus hirtellus*, under stones.
3. *Carcinus mænas*, common.
4. *Portunus puber*, common.
5. *Portunus arcuatus*, 4 fms.
6. *Macropodia* (*Stenorhynchus*) *rostrata*, common.
7. *Hyas araneus*, generally distributed.
8. *Hyas coarctatus*, generally distributed.
9. *Eupagurus bernhardus*, generally distributed.
10. *Eupagurus prideaux*, across mouth of bay.
11. *Porcellana longicornis*, under stones.
12. *Galathea squamifera*, under stones, abundant.
13. *Galathea intermedia*, off Breakwater, common.

FIG.

14. *Galathea strigosa*, under stones, rare.
15. *Astacus gammarus* (=*Homarus vulgaris*) on rocky ground all round bay.
16. *Crangon vulgaris*, common in sandy places.
17. *Crangon trispinosus*, off Breakwater.
18. *Crangon fasciatus*, 4 fms.
19. *Hippolyte varians*, common.
20. *Pandalus annulicornis*, common.
21. *Macromysis flexuosa*, common in summer.
22. *Macromysis inermis*, common in summer.
23. *Mysidopsis gibbosa*.
24. *Gastrosaccus sanctus*.
25. *Haplostylus normanii*.
26. *Siriella armata*.
27. *Nebalia bipes*, under stones.
28. *Eudorella truncatula*.
29. *Dynamene rubra*, on weeds.
30. *Idotea marina*, on weeds.
31. *Idotea viridis*, on weeds, Breakwater.
32. *Ligia oceanica*, in damp places above high water.
33. *Hyale nilssonii*, on weeds, Breakwater.
34. *Orchestia littorea*, abundant at high water.
35. *Bathyporeia pelagica*, abundant.
36. *Stenothoe monoculoides*, in rock pools.
37. *Metopa bruzellii*.
38. *Monoculodes carinatus*, outside bay.
39. *Perioculodes longimanus*.
40. *Pontocrates arenarius*, common.
41. *Synchelidium haplocheles*.
42. *Apherusa jurinii*, in rock pools.
43. *Paratylus swammerdamii*.
44. *Dexamine thea*.
45. *Tritæta gibbosa*, on *Morchellium argus*.
46. *Gammarus marinus*, among weeds.

FIG.
47. *Gammarus locusta,* among weeds.
48. *Melita palmata.*
49. *Cheirocratus assimilis.*
50. *Aora gracilis.*
51. *Microprotopus maculatus.*
52. *Podoceropsis excavata,* outside bay.
53. *Amphithoe rubicata,* among weeds.
54. *Podocerus falcatus,* on Breakwater.
55. *Pleonexes gammaroides,* in rock pools.
56. *Janissa capillata,* on Breakwater.
57. *Erichthonius abditus.*
58. *Siphonœcetes colletti.*
59. *Corophium bonellii.*
60. *Phtisica marina.*
61. *Protella phasma,* on Breakwater.
62. *Pariambus typicus,* on *Asterias rubens.*
63. *Caprella linearis,* on weeds, Hydroids, etc.
64. *Caprella acanthifera,* on weeds, Hydroids, etc.

Plate VI.

Key to the Chart, showing the distribution of the Mollusca.

FIG.
1. *Anomia ephippium,* common on stones.
2. *Pecten varius,* small, under stones.
3. *Pecten opercularis,* off Castles and Bradda Head.
4. *Pecten maximus,* small, off Castles.
5. *Mytilus edulis,* in crevices of rocks.
6. *Mytilus modiolus,* small, in rock pools.
7. *Modiolaria discors,* among Corallina in pools.
8. *Nucula nucleus,* off Bradda.
9. *Pectunculus glycimeris,* dead but fresh, off Castles.
10. *Montacuta ferruginosa,* on *Echinocardium,* in sand.
11. *Lasæa rubra,* in empty shells of *Balanus.*
12. *Lucina borealis,* dead but fresh, not common.

FIG.

13. *Cardium echinatum*, 10 fms.
14. *Cardium edule*, in sand.
15. *Cardium norvegicum*, dead but fresh, off Castles.
16. *Venus exoleta*, dead but fresh, off Breakwater, and Castles.
17. *Venus lincta*, dead but fresh, off Castles.
18. *Venus fasciata*, in sand.
19. *Venus casina*, off Castles.
20. *Venus gallina*, in sand.
21. *Tapes virgineus*, off Castles.
22. *Tapes pullastra*, in muddy gravel.
23. *Tellina balthica.*
24. *Psammobia ferroënsis*, dead but fresh, scarce.
25. *Donax vittatus*, in sand.
26. *Mactra solida*, in sand.
27. *Mactra stultorum*, scarce.
28. *Lutraria elliptica*, in mud.
29. *Scrobicularia alba*, in sand, common.
30. *Solen ensis*, in sand.
31. *Solen siliqua*, in sand, abundant.
32. *Saxicava rugosa*, off Castles.
33. *Chiton albus*, under stones.
34. *Chiton lævis*, under stones.
35. *Patella vulgata*, abundant.
36. *Helcion pellucidum*, on *Laminaria.*
37. *Tectura testudinalis*, under stones.
38. *Emarginula fissura*, under stones.
39. *Trochus magus*, along N. side of bay.
40. *Trochus cinerarius*, common.
41. *Trochus umbilicatus*, common.
42. *Trochus zizyphinus*, common.
43. *Trochus montacuti*, off Castles.
44. *Phasianella pullus*, off Breakwater.
45. *Littorina obtusata*, abundant.

FIG.

46. *Littorina rudis*, abundant.
47. *Littorina littorea*, common.
48. *Lacuna divaricata*, S. side of bay, 4 fms.
49. *Rissoa parva*, common.
50. *Rissoa cingillus*, off Breakwater.
51. *Rissoa striatus*, off Breakwater.
52. *Odostomia rufa*, off Breakwater.
53. *Natica alderi*, off Breakwater.
54. *Lamellaria perspicua*, under stones.
55. *Aporrhaïs pes-pelicani*, across mouth of bay.
56. *Purpura lapillus*, abundant.
57. *Buccinum undatum*, common.
58. *Murex erinaceus*, under stones.
59. *Nassa incrassata*, under stones.
60. *Cypræa europæa*, under stones.
61. *Bulla hydatis*, off Castles.
62. *Aplysia punctata*, across mouth of bay and N. side.
63. *Archidoris tuberculata*, on rocks and boulders in winter and spring.
64. *Jorunna johnstoni*, in rock pools.
65. *Lamellidoris proxima*, under stones.
66. *Doris diaphana*, under stones, rare.
67. *Goniodoris castanea*, under stones.
68. *Polycera quadrilineata*, across mouth of bay.
69. *Ancula cristata*, off Breakwater.
70. *Hermæa dendritica*, in rock pools.
71. *Doto coronata*, off Breakwater.
72. *Facelina drummondi*, off Breakwater.
73. *Galvina tricolor*, off Breakwater.
74. *Galvina cingulata*, off Breakwater.
75. *Sepiola atlantica*, across mouth of bay.
76. *Eledone cirrosa*, occasionally at low spring tides.

Plate VII.

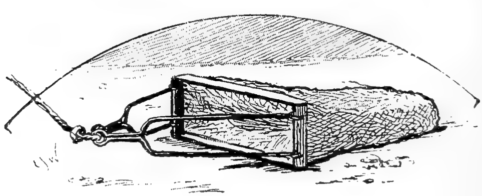
Key to the Chart showing the distribution of the Polyzoa and Tunicata.

FIG.

1. *Gemellaria loricata*, off Breakwater.
2. *Canda* (*Scrupocellaria*) *reptans*, on boulders and off Breakwater.
3. *Scrupocellaria scrupea*, off Bradda Head and Breakwater.
4. *Bicellaria ciliata*, on Breakwater.
5. *Bugula flabellata*, off Bradda Head.
6. *Bugula calathus*, off Bradda Head.
7. *Beania mirabilis*, off Breakwater.
8. *Membranipora pilosa*, on various brown algæ.
9. *Membranipora membranacea*, on *Laminaria* and *Fucus*
10. *Membranipora lineata*, on *Fuci*, common.
11. *Membranipora spinifera*, on stones.
12. *Membranipora flemingii*, on stones and shells.
13. *Schizoporella spinifera*, on roots and stems of *Laminaria*.
14. *Schizoporella unicornis*, under stones and on *Laminaria*.
15. *Schizoporella hyalina*, on shells and stones.
16. *Lepralia pallasiana*, on shells and stones.
17. *Umbonula verrucosa*, on boulders and stones.
18. *Mucronella coccinea*, on stones and *Laminaria*.
19. *Crisia cornuta*, under surfaces of boulders.
20. *Alcyonidium hirsutum*, on algæ.
21. *Flustrella hispida*, on *Fuci*.
22. *Amathia lendigera*, off Breakwater.
23. *Bowerbankia imbricata*, on *Corallina* in pools.
24. *Valkeria uva*, on *Fuci* and *Corallina*.
25. *Pedicellina cernua*, on algæ on Breakwater and Bradda Head.

FIG.

26. *Botryllus smaragdus*, under stones and on *Laminaria*.
27. *Botryllus violaceus*, under stones.
28. *Botryllus schlosseri*, under stones.
29. *Botrylloides rubrum*, under stones.
30. *Distoma rubrum*, in shore pools.
31. *Morchellium argus*, on stones and roots of *Laminaria*.
32. *Morchellioides alderi*, in rock pools.
33. *Amaroucium proliferum*, on stones.
34. *Leptoclinum candidum*, under stones.
35. *Leptoclinum asperum*, under stones and on algæ.
36. *Diplosoma gelatinosum*, in rock pools.
37. *Clavellina lepadiformis*, in Pat's Dub and off Breakwater.
38. *Ciona intestinalis*, in rock pools and off Breakwater.
39. *Ascidia mentula*, off Castles.
40. *Ascidiella aspersa*, on stones and off Breakwater.
41. *Styelopsis grossularia*, off Castles.
42. *Molgula citrina*, under stones.
43. *Cynthia*, sp. under stones.



Appendix A.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1900).

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

Prof. R. J. Harvey Gibson, M.A., F.L.S., Liverpool.

His Excellency Lord Henniker, Governor of the Isle-of-Man.

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.

W. E. Hoyle, Esq., M.A., Owens College, Manchester.

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

A. Leicester, Esq., formerly of Liverpool.

Sir James Poole, J.P., Liverpool.

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

I. C. Thompson, Esq., F.L.S., Liverpool, Hon. Treasurer.

A. O. Walker, Esq., F.L.S., J.P., Maidstone.

Arnold T. Watson, F.L.S., Sheffield.

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 or Laboratory Assistant, 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, to see the Aquarium and the Station, so long as it is found not to interfere with the scientific work. Occasional lectures are given 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 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.

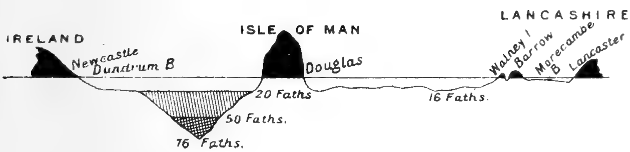
VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away 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

* Workers at the Station can always find comfortable and convenient quarters at the closely adjacent Bellevue Hotel; but lodgings can readily be had by those who prefer them.

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.



Appendix B.

HON. TREASURER'S STATEMENT.

As usual the list of subscribers and the balance-sheet are appended.

The appeal made by the Director in a previous Report for an additional income of about £100 per annum, to be utilised in publishing well-illustrated papers and memoirs, embodying the results of local biological investigations, has been generously responded to by Mr. F. H. Gossage and by Mrs. Holt by donations for the last two years (see Report). This fund is being separately applied for the publication of a valuable series of well-illustrated Biological Memoirs now appearing, the accounts of which are kept distinct from the L.M.B.C. funds.

The Hon. Treasurer will be glad to receive the names of new subscribers, with the view of continuing these publications, and further adding very materially to the already excellent work achieved under the auspices of the L.M.B.C. since its foundation, sixteen years ago.

Isaac C. Thompson, Hon. Treasurer.

SUBSCRIPTIONS AND DONATIONS.

	Subscriptions. £ s. d.	Donations. £ s. d.
Ayre, John W., Ripponden, Halifax ...	1 1 0	—
Bateson, Alfred, Harrop-road, Bowdon...	1 1 0	—
Bickerton, Dr., 88, Rodney-street ...	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	—
Byne, L. St. George, Norton Manor, Taunton	1 0 0	—
Caton, Dr., 86, Rodney-street	—	1 1 0
Clague, Dr., Castletown, Isle of Man ...	1 1 0	—
Clubb, J. A., Public Museums, Liverpool	0 10 6	—
Cole, F. J., Liverpool (research table) ...	1 1 0	—
Coombe, John N., 4, Paradise-square, Sheffield	1 1 0	—
Comber, Thomas, J.P., Leighton, Parkgate	1 1 0	—
Crellin, John C., J.P., Andreas, I. of Man	0 10 6	—
Gair, H. W., Smithdown-rd., Wavertree	2 2 0	—
Gamble, Col. C.B., Windlehurst, St. Helens	2 0 0	—
Gamble, F.W., Owens College, Manchester	1 1 0	—
Gaskell, Frank, Woolton Wood	1 1 0	—
Gaskell, Holbrook, J.P., Woolton Wood	1 1 0	—
Gibson, Prof. R. J. Harvey, Waterloo ...	1 0 0	—
Gotch, Prof., Museum, Oxford	1 1 0	—
Halls, W. J., 35, Lord-street	1 1 0	—
Hanitsch, Dr., Museum, Singapore ...	1 1 0	—
Forward...	£31 1 0	1 1 0

	Subscriptions. £	s.	d.	Donations. £	s.	d.
Forward ...	£31	1	0	1	1	0
Harmer, F. W., Cringleford, Norwich ...	1	1	0		—	
Headley, F. W., Haileybury College, Hertford	1	10	0		—	
Henderson, W. G., Liverpool Union Bank	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 ...	1	0	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., Field House, Wavertree	1	0	0		—	
Kermode, P. M. C., Hill-side, Ramsey ...	1	1	0		—	
Lea, Rev. T. Simcox, St. Ambrose Vicarage, Widnes	1	1	0		—	
Lea, Mrs. T. Simcox, Widnes	1	1	0		—	
Leicester, Alfred, Aston Clinton, Bucks	1	1	0		—	
Lewis, Dr. W. B., West Riding Asylum, Wakefield	0	10	0		—	
Manchester Microscopical Society ...	1	1	0		—	
Meade-King, H.W., J.P.. Sandfield Park	1	1	0		—	
Meade-King, R. R., 4 Oldhall-street ...	0	10	0		—	
Meldrum, T. F., Ashley-road, Bowdon...	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		—	
Forward...	£67	14	6	1	1	0

	Subscriptions. £	s.	d.	Donations. £	s.	d.
Forward...	67	14	6	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston	1	1	0		—	
Rathbone, Miss May, Backwood, Neston	1	1	0		—	
Rathbone, W., Greenbank	2	2	0		—	
Roberts, Isaac, F.R.S., Crowborough ...	2	2	0		—	
Simpson, J. Hope, Annandale, Aigburth-drive	1	1	0		—	
Smith, A. T., junr., 24, King-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		—	
Turner, C., Agamemnon-road, West Hampstead, London	1	0	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		—	
	£92	17	6	1	1	0

SUBSCRIPTIONS FOR THE HIRE OF COLLEGE "WORK-TABLES."

	£	s.	d.
Owens College, Manchester	£10	0	0
University College, Liverpool	10	0	0
	£20	0	0

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

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

1900.	£	s.	d.
To Balance due Treasurer, Dec. 31st, 1899	2	3	8
,, Printing Reports and Engraving Plates	16	1	11
,, Printing and Stationery	2	16	8
,, Expenses of Dredging Expeditions	23	8	6
,, Boat Hire	2	5	0
,, Books and Apparatus at Port Erin Biological Station	28	5	2
,, Postage, Carriage of Specimens, &c.	3	6	5
,, Salary, Curator	90	0	0
,, Research Assistant	14	0	0
,, Rent of Port Erin Biological Station	15	0	0
,, Sundries	1	10	6
	£198	17	10

1900.	£	s.	d.
By Subscriptions and Donations received	98	0	6
,, Amount received from Colleges, &c., for hire of "Work Tables"	20	0	0
,, Dividend, British Workman's Public House Co., Ltd., Shares	9	18	0
,, Sale of Nat. Hist. Specimens	5	4	6
,, Sale of Reports and Volumes of Fauna	21	8	6
,, Interest on British Association (1896) Fund	38	6	8
,, Bank Interest	1	0	0
,, Admissions to Aquarium	4	10	9
,, Balance due Treasurer, Dec. 31st, 1900	0	8	11
	£198	17	10

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

ISAAC C. THOMPSON,
HON TREASURER.

Audited and found correct,
A. T. SMITH, JUNR.

LIVERPOOL *December* 31*st*, 1900.

PLATE I.


CHART OF THE
SOUTH-WESTERN CORNER OF
THE ISLE OF MAN
SHOWING THE DISTRIBUTION OF ITS
MARINE FAUNA.
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
SPANISH HEAD.
CALF OF MAN.

PLATE II.

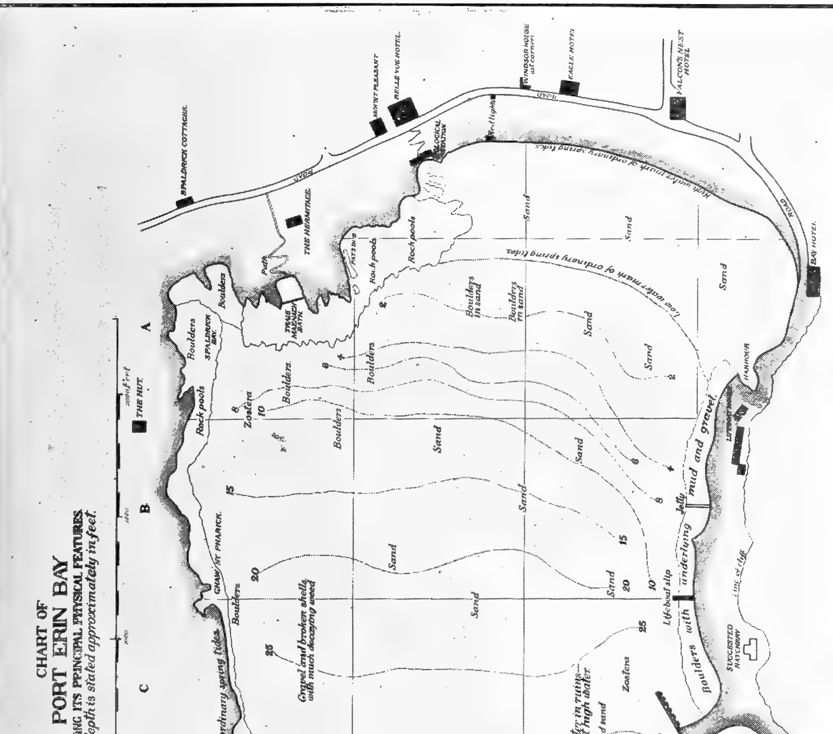


CHART OF
PORT ERIN BAY
SHOWING ITS PRINCIPAL PHYSICAL FEATURES.
The depth is stated approximately in feet.
1/2 Mile.
BRADDA HEAD.
MILNER TOWER.
THE SKER.
SPALDRICK COTTAGES.
THE HERMITAGE
SPALDRICK BAY.
THE HUT.
MOUNT PLEASANT
BELLE VUE HOTEL.
WINDSOR HOUSE
EAGLE HOTEL
FALCON'S NEST HOTEL
BAY HOTEL.
HARBOUR
SUGGESTED HATCHERY
THE CASTLES.
High water mark of ordinary spring tides.
Low water mark of ordinary spring tides.
Breakwater in ruins covered at high water
Boulders with underlying mud and gravel.
Lifeboat slip
Jetty
Buoy
Magnetic
Gravel and broken shells
Gravel, sand and broken shells
Gravel and broken shells with much decaying weed
Gravel and dead shells, much living and decaying weed
Gravel and sand
Boulders in sand
Rock pools
Zostera
Sand
Boulders
Road
Path

PLATE III.

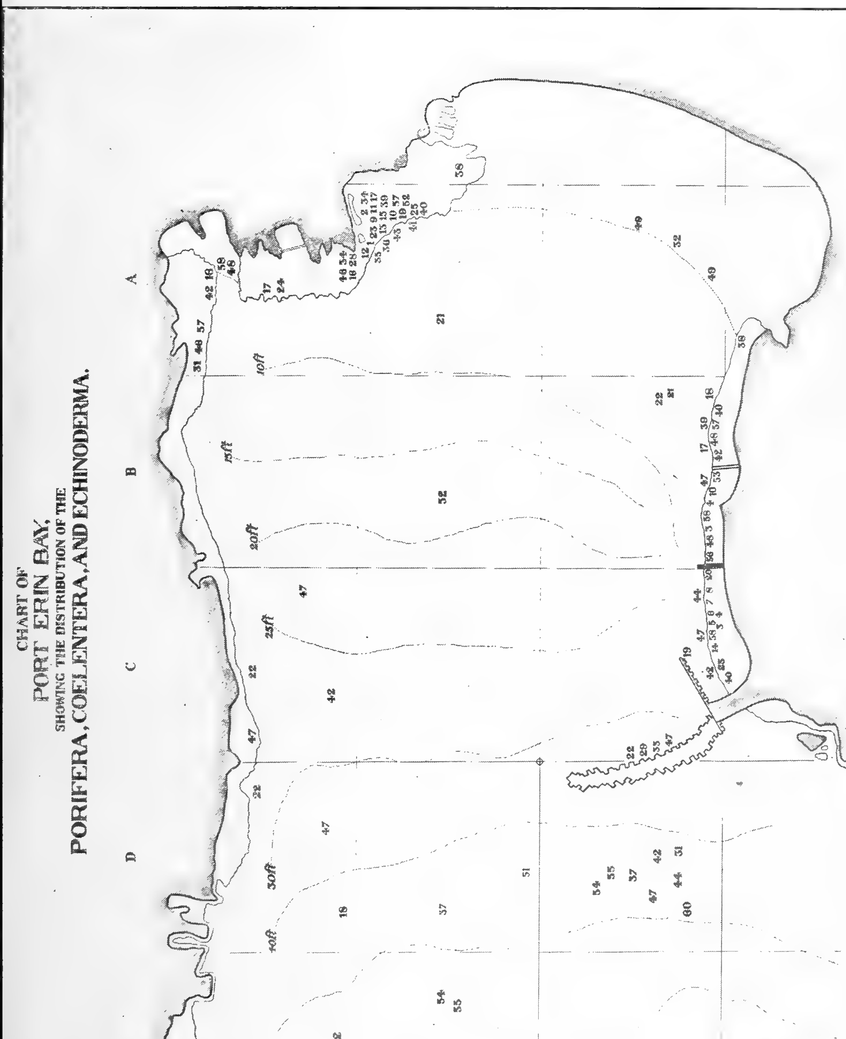


CHART OF
PORT ERIN BAY,
SHOWING THE DISTRIBUTION OF THE
PORIFERA, COELENTERA, AND ECHINODERMA.
10ft
15ft
20ft
25ft
30ft
40ft
50ft
60ft

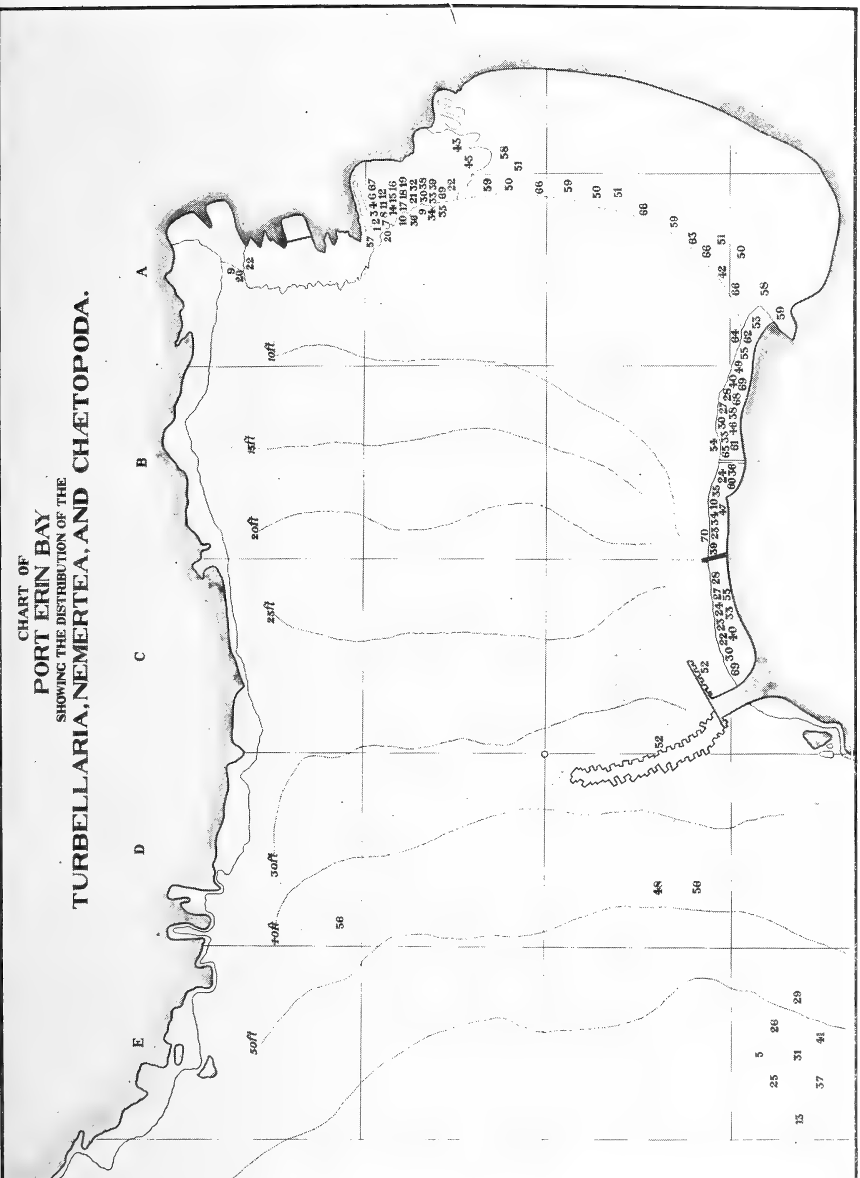


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
TURBELLARIA, NEMERTEA, AND CHÆTOPODA.
A
B
C
D
E
1
2
3
4
10ft
15ft
20ft
25ft
30ft
40ft
50ft
60ft

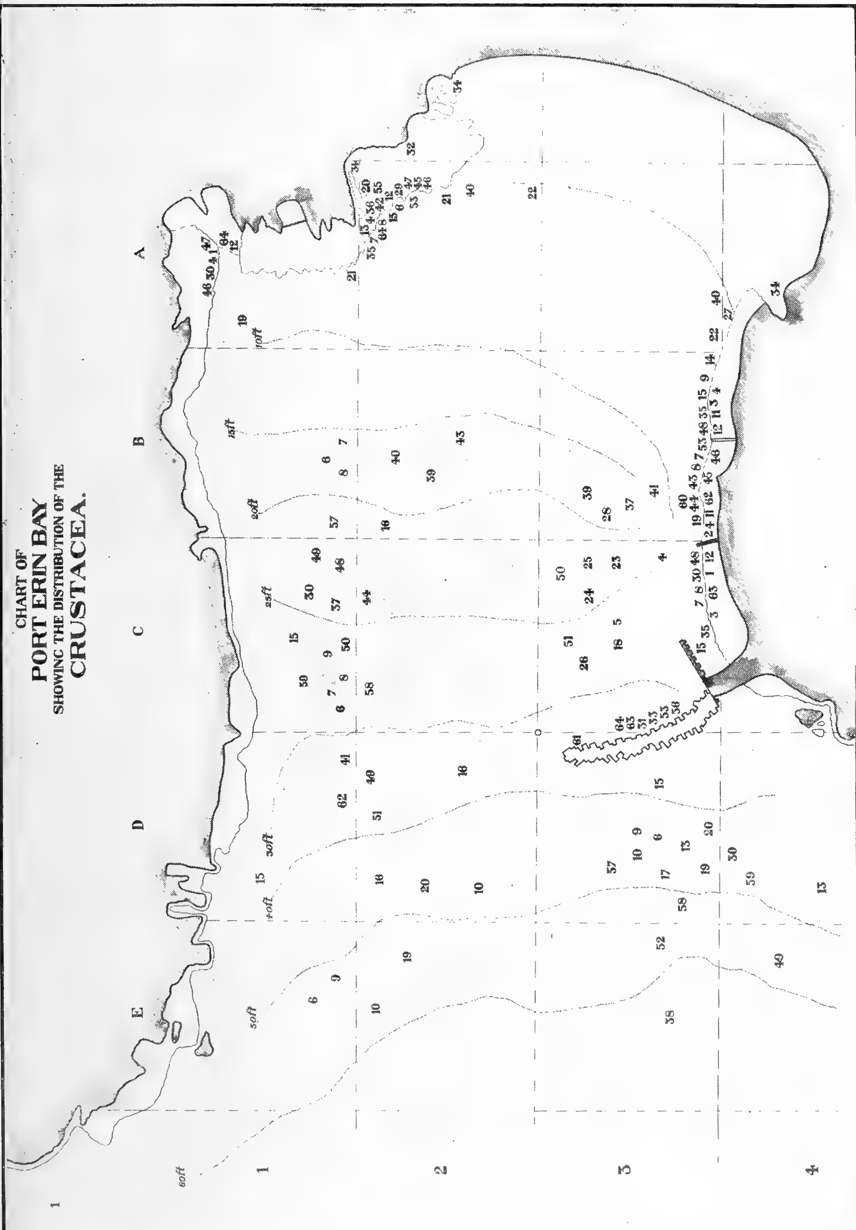


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
CRUSTACEA.

PLATE VI.

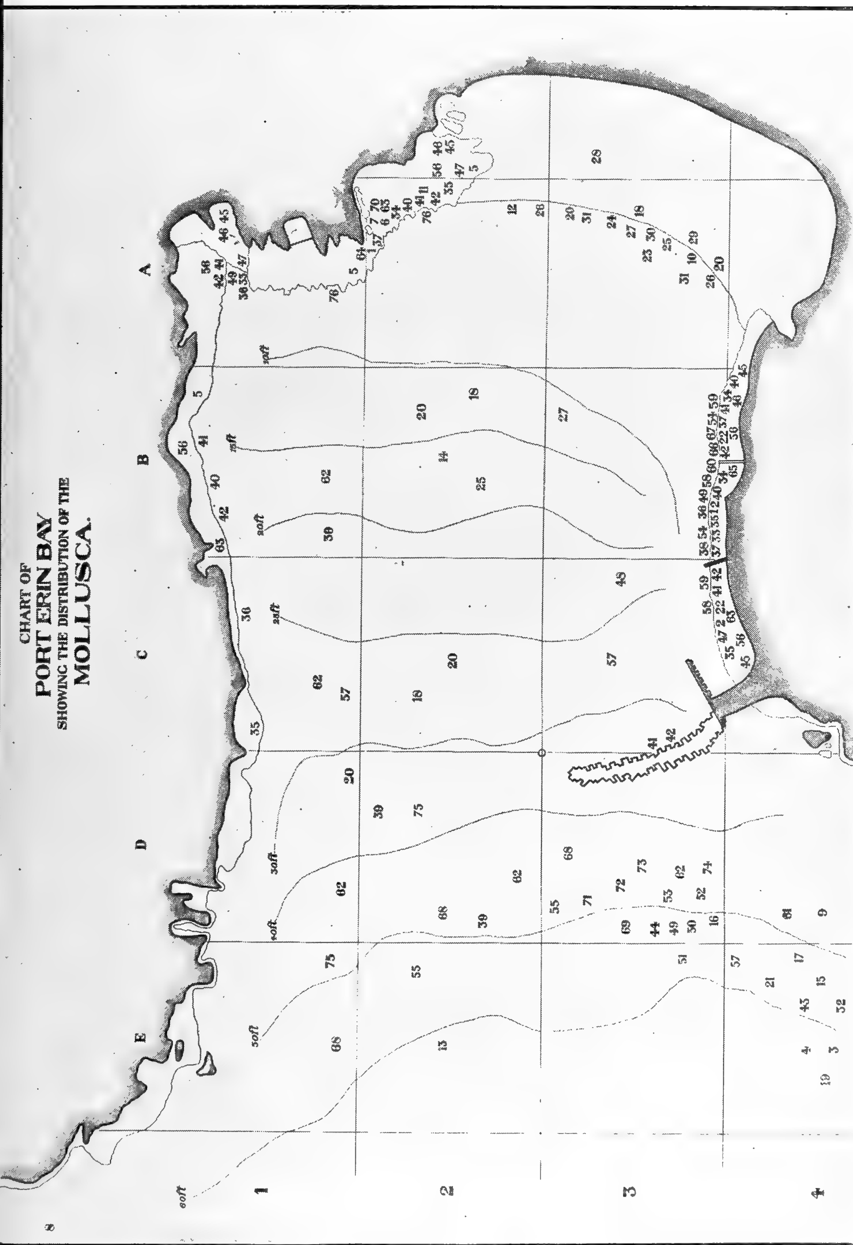


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
MOLLUSCA.
A
B
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PLATE VII.

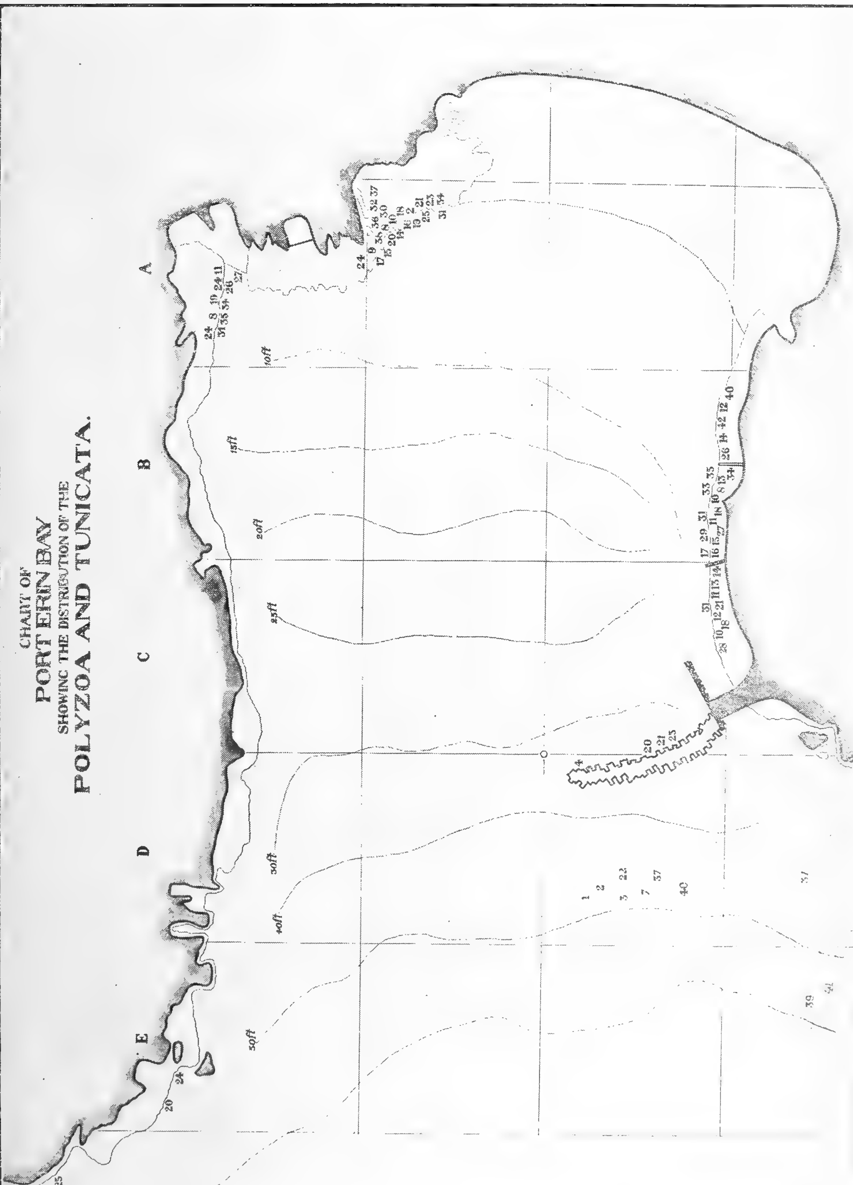


CHART OF
PORT ERIN BAY
SHOWING THE DISTRIBUTION OF THE
POLYZOA AND TUNICATA.

NOTE ON THE SPREAD OF THE FULMAR
(*Fulmarus glacialis*).

By J. Wiglesworth, M.D.

[Read December 14th, 1900.]

It is but a short time ago—less indeed than a quarter of a century—since the only known breeding station for the Fulmar Petrel in the British islands was the island group of St. Kilda, where, however, as is well known, it breeds in enormous numbers, and constitutes a valuable source of profit to the natives of that remote locality.

In June, 1878, however, a small colony of these birds established itself on the precipices of Foula, the most remote and inaccessible island of the Shetland group, and the birds have now become fairly plentiful there. Additional colonies have since been established in Shetland—on the island of Papa Stour and at Eshaness on the west coast of the mainland, on the cliffs of Hermaness and Saxaford in the island of Unst in the extreme north, and on the Noup of Noss on the east. The above particulars, which I have extracted from the recently published "Vertebrate Fauna of the Shetland Islands," by Buckley and Evans, I am able to supplement from my personal observations, as last year (1899) I had the pleasure of visiting the breeding station of this bird on the cliffs of Hermaness in the island of Unst in the extreme north of Shetland, a few details of which may perhaps prove of interest. It is not known when the Fulmar first established itself on Hermaness, but it may be taken as certain that the bird did not breed there in Saxby's time. When I first visited that locality in the summer of 1895, whilst rowing round the skerries and cliffs on the northern part of the island, I saw a few

Fulmars flying about the Hermaness range, and as it was then early in June, I thought it probable that they might be breeding there, though I was not able at that time to verify the supposition. The birds were very few in number, but I only visited at that time a portion of the cliff range where the birds have now taken up their abode, so that there might have been more than appeared at first sight. There is no doubt, however, that since that date the bird has increased very considerably, and there is now a large and flourishing colony scattered along the range of the Hermaness cliffs, and on the detached and semi-detached stacks which project out from this wild, storm-beaten coast line. Towards the end of May, 1899, I made a careful inspection of this region, spending one day in working the cliffs from the land side, and on the following day exploring some of the stacks by boat. The sitting birds were then scattered in suitable, and for the most part decidedly inaccessible, situations along this range of cliffs and the outstanding stacks for a distance of a quarter of a mile or more, and numerous other birds were constantly flying around. It was very difficult to estimate their numbers accurately, some portions of the cliff being entirely untenanted, and then one would come to spots where several birds were sitting on ledges within a few feet of each other. Probably 100 pair would be a conservative estimate for the number scattered about the Hermaness district, and I did not visit the cliffs of Saxaford on the opposite side of Barrafirth, where, as I have before stated, another fair-sized colony exists. The sitting birds were seen in all situations on the face of the cliff, and some were occupying turfy banks near the bottom, but on the whole it seemed to me that the most favoured nesting sites were ledges some 25 to 30 feet from the top, especially in places where the cliff overhung somewhat. My first endeavours to get at the nesting ledges were unsuccessful, as after descending some 20 feet by the aid of a rope, and getting within a dozen feet or so of some sitting birds, I had to abandon the attempt owing to the overhanging nature of the cliff, and the very loose, crumbly character of the foothold, portions of the rock being detached at almost every step. It was what a Shetlander would call a very "rotten bank." The birds sat very close, and were with difficulty got to stir except when a missile lit almost on them. The following day, however, finding some occupied ledges some 25 feet below the top of one of the stacks where the rock face was perfectly firm, I was able to descend with a rope without difficulty, and obtained several eggs. The birds did not sit quite so close as those I had endeavoured to get at the previous day, but I observed one of them remain at her post until my companion got within about 10 feet of her, when, before leaving, she twice ejected from her mouth for a distance of two or three feet the thin amber-coloured, oily liquid, which the bird is well known to part with under these circumstances. The liquid, I may observe, was ejected from the throat, after the fashion of a regurgitation, and not squirted through the nostrils, as the older authors asserted. The other birds, however, on this set of ledges took their departure without going through this performance. The eggs were laid on broad ledges, which were covered with a coarse, sandy detritus and small, flat flakes of stone, which had fallen down from the rocks above. There was not the smallest trace of a nest, and there was merely the very shallowest depression on the sandy detritus on which the single egg rested. The egg, indeed, lay as open and exposed as a Guillemot's on its rocky ledge, and the choosing by the bird of ledges covered with this coarse detritus had probably a relation to the safety of the egg, which would run no risk of rolling off, as it would do if the surface on which it was laid were perfectly smooth and bare, after the fashion of the Guillemot's nesting ledge, the egg of the Fulmar not having the protective shape of that of the Guillemot to prevent it from rolling.

J. MacGillivray, who visited St. Kilda in 1840, states that whilst the Fulmar breeds on the face of the highest precipices, it only does so on such as are furnished with small grassy shelves; and Dixon, who visited the same locality some fifteen years back, in part confirms this, for he states that whilst the bird also bred on bare ledges, its favourite nesting sites were portions of cliff where a good layer of turf-clad soil was present, adding that the bird appeared to prefer to burrow a short distance into the ground whenever possible. The observations I have just given from Hermaness show, however, that the birds take quite as readily to perfectly bare open ledges as to those covered with turfy soil.

All the eggs taken on that date (May 26th) were perfectly fresh and clean, so that the birds had apparently just started laying.

In addition to the localities already given in the Shetlands, I am able to add another from my experience of last summer (1900) in the extreme south-west of that group; for in June last, whilst rowing round the cliffs in the neighbourhood of Fitful Head, three or four of these birds flew round my boat for some little time. Although I was not able to detect any sitting birds on the cliffs, I feel very little doubt from my experience of other localities that they were nesting there.

The facts I have just given point to a very considerable and very remarkable extension of the breeding range of this bird within the last quarter of a century, and it is a matter of interesting conjecture what causes have operated to bring it about, for so far as we can judge, the usual causes of extension of range of a species are absent in this case. We are familiar with many instances in which birds have increased notably within recent times, owing to the extension of favouring conditions. The Missel Thrush, for example, has greatly extended its range within the present century in harmony with the increase throughout the country of the plantations it loves to frequent; and similar instances might be given of woodland birds, such as the Blackcap, having followed the planting of shrubberies into localities where they had previously been unknown. But in all such cases there has been a change in the environment which the birds have taken advantage of, and no such explanation is applicable in the case of the Fulmar.

The beetling cliffs of Shetland, which are now in process of being colonised by these birds, are the same now as they have been for ages, and can show no greater attractions at the present time than they presented centuries ago. Nor does there seem any reason to suppose that any difference in the food supply furnished by the Shetland seas can enter into the case, for though the stranded carcase of a dead whale is said to have attracted the first birds to Foula, the influence of this is at least very problematical, nor would it account for the continued steady spread of the birds.

Has any change occurred in its stronghold at St. Kilda to cause the bird to seek out fresh breeding haunts? Of this I can find no evidence. It is true indeed that the population of St. Kilda has diminished notably since Martin's day, when the islands supported 180 persons; but there has been no considerable change for many years past, the population appearing to average some 70 to 80 souls. And so far as I know the bird is as much prized and as largely sought after by the St. Kildans as ever, and I know of no evidence in favour of its having multiplied there beyond its usual numbers within recent times. But there is indeed no proof that the colonies of Fulmars which are now established in Shetland have ever come from St. Kilda. Is it not equally likely that they may be offshoots from the vast colonies of this bird which people Iceland, Spitzbergen, and other places in the far North, and that what we are witnessing is a southern extension of the breeding range of this species? If this be so, it is at least a reasonable conjecture that a climatal change in the direction of greater coldness and retardation of the springs may be in course of progress, and that this is at the bottom of the phenomenon we are considering. It is not a very comfortable reflection that our climate may possibly be getting colder, but the evidence in favour of it, which the spread of the Fulmar suggests, is not altogether confined to that bird. There are certain other northern breeding birds which have only been discovered to breed in the northern parts of our islands within comparatively recent times, and which appear to be now on the increase. The Snow Bunting (*Plectróphenax nivalis*) is a case in point. First discovered to be nesting in Unst by Saxby in the year 1861, it has since been found to breed on several of the higher Scotch mountains, and though it may very probably have bred in those regions years before the actual discovery of the nest, there seems no doubt that the species is now on the increase there. Some of the northern breeding Ducks again, such as the common Scoter (*Fuligula nigra*), and the Goosander (*Mergus merganser*), which have for many years past been known to breed sparingly in the Highlands, chiefly in Sutherland and Caithness, appear to be on the increase as breeding species, though the possibility in these cases of the increase being due, in part at any rate, to additional even if unintentional protection afforded, must not be lost sight of.

There is some little evidence also in favour of the theory here suggested from another standpoint. There appears to be a fairly general belief in Shetland amongst shepherds and others that the springs are now colder than used to be the case. Vague opinions of this sort are no doubt seldom trustworthy, but I have spoken to intelligent shepherds, on Noss for instance, who have informed me that it no longer paid to keep sheep as formerly, as owing to the coldness of the springs, the grass was so late in appearing that there was not enough food for the lambs. Without attaching too much importance to it, this opinion is, I think, worth recording, for so far as it goes it tends to confirm the theory I have put forward as to a climatal change being at the bottom of the extension of the breeding range of such birds as the Fulmar and the Snow Bunting.

I do not wish for a moment to be understood as considering that this theory is in any way proved, for the evidence is at best but fragmentary, and the facts may admit of a wholly different interpretation; but there is at least the possibility that it may be true, and that the spread of the Fulmar may be one of the first evidences of the change.

L.M.B.C. MEMOIRS.

No. V. ALCYONIUM.

BY

SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.

Introduction.

The Order Alcyonaria is represented in the British seas by very few species; and as none of these are commonly found between tide marks nor thrown up on the beach by storms, they are very little known to the general public. The Alcyonarian which is best known to the public is the precious coral of commerce, *Corallium rubrum,* from the Mediterranean Sea, but other Alcyonarians, such as the Organ pipe coral (*Tubipora*), the Blue coral (*Heliopora*), the Sea-fans (Gorgonacea) and the Sea-pens (Pennatulacea) are familiar objects in our Zoological Museums.

When a living Alcyonarian is examined in sea-water a number of tubular radially symmetrical bodies are seen to project from the surface, each of which is provided at its free extremity with eight pinnate tentacles arranged in a circle round a slit-like mouth. When the water is disturbed, or the Alcyonarian removed from the water, these bodies slowly retract beneath the surface of the coral, until their presence is indicated only by an eight-rayed star-like aperture. These bodies are usually called the polyps, and they undoubtedly possess many features of general resemblance to the well-known fresh-water polyp Hydra. A critical examination of the anatomical structure of the Alcyonarian, however, proves that the name "polyp" is misapplied in this case, for the bodies referred to only correspond with a part of the polyp of the Hydra, namely, the free end with the crown of tentacles, the greater part of the fixed or proximal end of the Alcyonarian polyp being buried in the massive substance of the coral. We have, in other words, two parts in the body of the Alcyonarian polyp,—(i.) a part which is free and can be retracted or expanded at will, and (ii.) a part which is attached and firmly welded to the corresponding parts of neighbouring polyps.

With this explanation of the general structure the reader is prepared to understand the critical or diagnostic features by which a given specimen may or may not be referred to the Order Alcyonaria.

The ALCYONARIA are Coelenterata which (with one or two rare exceptions) form colonial organisations by budding. The individual polyps composing the colony are provided with eight tentacles at their free extremity, and each of these tentacles is provided with two or more rows of papilliform processes called pinnules, giving the tentacles a feathered or pinnate form.

The form which the Alcyonarian colony takes varies immensely in the different families into which the Order is divided; some being encrusting plates, some lobular in form, some shrubby, some mushroom shaped, and so on, but a detailed description of these forms would take me beyond the scope of this memoir. The important point to note here, however, is that although there is a remarkable similarity in the form of the polyps of any one species, the shape of the colony has wide limits of possible variation, and consequently a definition of it is almost impossible.

In other respects, too, the species vary. The colour, for example, is sometimes constant, but more generally subject to considerable variation, and the spicules, which are often very characteristic in form, more frequently are subject to modification in size and form from that which is regarded as typical of the species.

The reproduction of the Alcyonarians is remarkably constant. A few species are viviparous, the young being born as solid, oval, ciliated larvæ, which swim away and then settle down to found a new colony. In the majority of cases, however, the eggs and sperms are discharged into the water simultaneously by the male and female colonies, fertilisation is effected in the water, and solid oval embryos are produced similar to those of the viviparous species. No other larval form is known in the group, and nothing occurs in the development of any species of the nature of an alternation of generations.

With the exception of the Precious Coral, the axis of which is used by jewellers, none of the Alcyonarians have any market value. Nor do the Alcyonarians, so far as we know at present, form an important article of food for fish or indeed any other marine animals. It is true that occasionally fragments of Pennatulids are found in the stomachs of Codfish, but there is no reason to believe that they form a frequent nor a favourite diet.* It is possible that at the spawning period of the Alcyonarians many of the eggs and embryos are devoured, but of this there is at present no definite evidence.

* The Haddock is sometimes found with pieces of the Pennatulid *Virgularia* in its stomach. *Vide* A. M. & W. F. Marshall, Report on the Oban Pennatulida, Birmingham, 1882.

Alcyonium digitatum.

This species has a very wide distribution in the British area, and may be regarded as one of the most abundant of British marine animals, as it appears to be capable of adapting itself to a very great range of natural conditions; but although so common, it is not found in many places at low tides. It is found in great numbers growing on the shells of Pectens, Cardiums, and other Mollusca on sandy, gravelly or shelly trawling grounds. It occurs attached to rocks which are exposed at low tides, and even on iron pillars of piers just below low-water mark, and encrusting worm tubes on muddy bottoms. Its vertical range extends from shallow water to a depth of 383 fathoms ("Caudan"), but probably depths of 35-40 fathoms, *i.e.*, the usual limit of wave action (as Allen has pointed out) are most suitable for its maximum growth and development. Geographically it extends from the coast of Norway (Hardanger fjord) to the Bay of Biscay, and it seems probable that there is no considerable extent of the British area which is free from it. I am indebted to Mr. Chadwick for the following notes as to the distribution of *Alcyonium digitatum* in the L.M.B.C. district. "Very small colonies are sometimes found at extreme low-water mark in Port Erin Bay, and large ones, of both colour varieties, occur in large numbers on the blocks of concrete forming the now ruined breakwater. We occasionally dredge colonies from depths of 12 to 15 fathoms in this neighbourhood. I have seen several very fine ones brought up on the long lines used by our fishermen. The greatest depth of which we have a record is 21 fathoms, on North Bank, 7 miles W. of Peel. It is pretty generally distributed all round the Manx coast. *Alcyonium* used to be abundant and the colonies of large size on some reefs of sandstone exposed only at the lowest tides at Hilbre Island. It is still to be found there, but in diminishing quantity, owing to the increase of sewage and chemical refuse in the river Dee. Small colonies occur rarely at extreme low water mark on the beach at Beaumaris, and large ones may be found at the same level in the caves on the N. side of Puffin Island. I have dredged well-grown colonies from depths varying from 5 to 10 fathoms in the Menai Straits. Red Wharf Bay, Anglesey, depth 4 to 7 fathoms, is another Welsh locality."* An account of the distribution of *Alcyonium* in the Plymouth district is given by Mr. E. J. Allen in the Journal of the Marine Biological Association, Vol. V., No. 4, 1899.

The size of the colony varies from that of a small pin's head to six inches or more in height by eight inches in breadth, according to the age of the colony and the number of polyps of which it is composed. The shape also varies very considerably. In the Plymouth district I found the smallest forms to be flat encrusting plates, which soon become convex above, and then grow into dome-shaped and later spherical lumps, and similar stages are found at Port Erin and elsewhere. Until the colony reaches a height of 3 inches from the support on which it grows it is not branched, but the larger specimens are divided terminally into 2, 3, 4, 5 or 6 blunt lobes which have a very rough resemblance to large human toes (Plate I., figs. 1 and 2). As these lobes are nearly always arranged in one plane the popular name of "Dead men's toes" has been applied to the species.

The method of growth of the colony which is given here is not constant; but no systematic investigation has yet been made of the laws which govern the growth of this

* See also Herdman, L.M.B.C. Report No. I, 1886, on the Alcyonaria of L.M.B.C. district.

and other genera belonging to the Alcyonaria. The colonies which grow on worm tubes seem to require a broader base than the others, and several specimens have been obtained which appear to be mainly encrusting plates, the vertical growth being relatively very slight. The specimens which grow on rocks, on the other hand, usually exhibit a much narrower base of support, grow rapidly in height and branch earlier and more freely than others.

The colour is usually pale flesh-colour when the colony is fresh, but this soon fades in an aquarium, and the colony becomes white. Many freshly-caught colonies from Plymouth Harbour were quite pale when brought into the laboratory, but perhaps their conditions of life were not perfectly healthy. A yellow variety of several tints is frequently found. I have obtained specimens of it from the West Coast of Scotland, Port Erin, Puffin Island, the Bristol Channel and elsewhere. This colour is due to a fixed pigment in the spicules, and it shows no appreciable change after years of immersion in spirit. At Port Erin there are two distinct tints of the yellow variety recognised, the one paler and the other a deep orange. I do not think that a red colour in the spicules ever occurs in this species. The red Alcyonium discovered by Couch off the coast of Scotland is *Alcyonium glomeratum* of Hassall, and is distinct from *A. digitatum*, Linn, in various respects.

Reproduction.

Alcyonium digitatum is always dioecious. No hermaphrodite colonies have yet been observed. The eggs, when ripe, are of a yellowish-red colour, and are discharged into the water by the mouths of the polyps which bear them. At the same time of the year the ripe sperm sacs of the males which are always milky white in colour, and can therefore be readily distinguished from the ova, discharge great quantities of spermatozoa into the body cavity, and thence by way of the mouth into the water. Fertilisation is most probably effected in the water, and not in the body cavity of the female just before the discharge of the ova. If this is the case, the sexual act is a true process of spawning.

The exact time of spawning may vary in different localities. In the Plymouth district I have found, as a result of a six years' series of observations, that the spawning always occurs during the last fortnight in December and the first fortnight in January, and at no other time of the year. At Port Erin the spawning may be somewhat later, as I have examined larvæ captured with the Plankton at Easter, which I feel certain are the larvæ of *Alcyonium digitatum*.

Anatomy of the Colony.

When a colony of *Alcyonium* is cut across (Plate I., fig. 5) it will be seen to consist mainly of a number of parallel tubes perforating a semi-transparent gelatinous substance in which a number of small calcareous spicules are imbedded. Each of these tubes is the body cavity—or coelenteron—of a polyp, and the gelatinous substance is the mesogloea of the polyps fused together into a common mass.

When the colony is alive and in a healthy condition a number of delicate transparent polyp heads protrude from the surface of the colony. Each of these is provided with a mouth and eight pinnate tentacles, and the body-wall below the crown of tentacles encloses a single large cavity, which is continuous with the cavity of the tubes above-mentioned. A careful examination of the body-wall of the polyp heads with a microscope (Pl. II., fig. 15) reveals the fact that it consists of three layers, an outer layer of cells—the ectoderm, a middle homogeneous layer—the mesogloea and an inner layer of cells—the endoderm. If these three layers be traced down to the surface of the colony it will be found that the ectoderm is continued over the general surface of the colony as a covering or protective sheath, that the mesogloea is continuous with the gelatinous mass or mesogloea common to the individuals composing the colony, and that the endoderm forms an inner lining to the tubes almost to the base of the colony.

The colony then is formed of a number of individuals, each of which consists of two parts—a greater part below bound to its neighbours in a common mesogloea, and a smaller part above which is free.

This latter part can be introverted into the former for protection—in much the same way as the head of the tortoise can be withdrawn into the shelter of the carapace—and it may be distinguished by the name "anthocodia" suggested by Mr. Bourne. When the "anthocodia" is retracted the aperture of the tube or false mouth can be constricted and closed so as to give complete protection to the polyp, as seen by reference to Plate I., fig. 3, in which a series of stages of the retraction of the anthocodiæ is illustrated. This power which the colony possesses of completely closing the "false mouths" of the polyps is of some physiological interest, as it enables each polyp of the colony to retain in its cavity a sufficient supply of sea-water to maintain its vitality for a few hours when the tide is exceptionally low and the colony is exposed to the air. Without this power the delicate cells which cover the tentacles and body-wall of the anthocodiæ would be very quickly killed when the colony is taken from the sea. As it is, colonies of *Alcyonium* will retain their vitality for two or three days if packed in damp seaweed.

The number of the polyps in each colony increases with its age, young buds being formed between the older polyps all through the life of the colony. Each of these buds is formed from an outgrowth of one of the superficial canals (which may be seen to ramify in the mesogloea near the surface of colony—Pl. I., fig. 3) joining a corresponding depression from the ectoderm at the surface. The young polyps thus formed remain in communication with the neighbouring older polyps by the canal throughout life, but no new canalicular communications with these older polyps are formed at a later period excepting quite close to the surface. The connection, therefore, between the polyps composing the colony is that represented in Plate I. fig. 5. The cavities of the older polyps are here seen to extend to the base of the piece that is represented in section, the cavities of the younger polyps are connected at their bases with them by short canals, and these in their turn may be connected with the bases of still younger polyps in a similar manner.

The colonial mesogloea appears to be at first sight a homogeneous substance, but an examination with a simple magnifying lens shows that it bears, firstly, a number of small white calcareous bodies called "the spicules," secondly, the canals above-mentioned, and, thirdly, a number of very fine branching lines which might be mistaken for capillary tubes.

(i.) The spicules are small bodies varying in size according to their age, but when fully formed 0·1-0·3mm. in length. They are composed of calcium carbonate with a sparse organic matrix. They vary very considerably in shape belonging to the categories which specialists call "warted spindles" (Pl. III., fig. 21), dumb-bells (fig. 22), Ks (fig. 23), and simple crosses. They are formed in cells budded off from the superficial ectoderm, and are only newly formed at the surface. This accounts for the fact that they are always much more crowded at the surface than they are in the more deep-seated parts of the colony, and also for the fact that in the deeper parts the spicules are always of full size.

(ii.) The canals are seen most clearly near the surface of the colony (Plate I., fig. 3). They have a sinuous course and appear to anastomose freely. They probably serve the purposes of distributing nourishment and of maintaining an equilibrium in the water pressure of the polyp cavities.

(iii.) The fine lines, which look like capillary tubes, really consist of strings or rows of cells. They have no lumen, and consequently cannot serve the purpose of transmitting the circulating fluids of the body. We have no definite knowledge of their function, but it is probable that they are mainly concerned in the secretion of the mesogloea.

Anatomy of the Polyps.

The structure of the anthocodiæ can only be satisfactorily studied when they are fully expanded. When retracted the several organs are so tightly compressed that a correct interpretation of their structure is quite impossible. When fully expanded each anthocodia exhibits a terminal slit-shaped mouth (Pl. I., fig. 4) surrounded by a crown of eight tentacles. The tentacles have a row of short papilliform processes on each side, giving them what is called a pinnate form. The shape of the tentacles changes every moment, slowly extending and retracting or bending inwards and outwards as they are stimulated by minute particles floating in the water. In the living condition the tentacles and body wall of the anthocodiæ are very transparent, and many features of the anatomy can be seen without dissection.*

The details of anatomy that can be seen in a living anthocodia are as follows:—From the mouth there hangs down into the body cavity a short opaque throat—the stomodæum (*St.*)—which opens freely below. At this—the lower—aperture six short sinuous cords, the mesenterial filaments, arise attached to the free edges of six very thin vertical plates—the mesenteries (conf. Pl. I., fig. 4, Pl. II., fig. 15, *Mst.*)—and, in addition, there are two cords which pass straight down into the cavity of the polyp attached to the free edges of the two remaining mesenteries. These two straight cords are called the dorsal mesenterial filaments, and the mesenteries which support them the dorsal mesenteries. The other mesenteries are called the dorso-laterals, ventro-laterals and ventrals respectively.

Further details can only be studied in preparations made for microscopic examination.

Nematocysts.—The pinnules of the tentacles bear a number of very minute stinging organs—the nematocysts. They are extremely small (0·0075mm. in length), and may be easily overlooked. They are oval in shape, and when irritated discharge a plain unarmed thread (Pl. II., figs. 8, 9, 10 and 11). Each nematocyst is formed within a specialised ectodermal cell called the "cnidoblast."

The Stomodæum is lined internally by a columnar ciliated epithelium, usually thrown into a number of folds in the preparation. On one side there is a groove lined by specialised epithelium armed with relatively long

* The transparency varies in specimens from different localities. In some cases there are so many spicules in the anthocodia that the transparency is very considerably diminished, The figure 4 in Plate I. was drawn from a Plymouth specimen.

powerful cilia. This groove is the siphonoglyph (Pl. II., fig. 6). The siphonoglyph indicates the position of the ventral side of the polyp.

The Mesenteries.—The mesenteries are in the greater part of their course very thin, consisting of two layers of endoderm cells covering a thin sheet of mesogloea. In the region of the stomodæum, however, they exhibit longitudinal thickenings or ridges which support the muscular fibres that are principally concerned in the retraction of the anthocodia. The arrangement of these thickenings is very characteristic. They are all situated on the ventral faces of the mesenteries, so that in a transverse section the muscle ridges on the ventral mesenteries are face to face, and on the dorsal mesenteries they are back to back (Plate II., fig. 6).

In the last six months of the year all the mesenteries, with the exception of the two dorsals, bear a considerable number of spherical bodies which are ova or sperm sacs according to the sex of the colony (Plate III., fig. 20).

The two dorsal mesenterial filaments run straight down from the lower end of the stomodæum in the depths of the polyp cavities. In the cavities of the older polyps they may be traced almost to the base of the colony. The epithelium covering these filaments is columnar and ciliated, the cilia producing in life a current of water flowing towards the stomodæum. The other mesenterial filaments are of a perfectly different nature (Pl. II., fig. 15). They are much shorter than the dorsal filaments, and are covered by an epithelium densely packed with gland cells. Their function is to secrete a digestive juice upon particles of food which pass through the stomodæum.

The Endoderm lining the cœlenteric cavity in the anthocodia is composed of ciliated cubical cells closely packed to form an epithelium. In the lower parts of the tube the cells are not so tightly packed, and each one bears at its base a process containing a myophan thread (Pl. II., fig. 12). These threads are so arranged as to form a circular muscle band by the constriction of which the diameter of the tube may be diminished.

It is a perfectly easy operation to scrape away on to a glass slide a number of the endodermal myo-epithelial cells in *Alcyonium*, and mount them for microscopic examination. As a matter of fact they afford us the most readily accessible example of this kind of cell which can be procured.

THE NERVOUS SYSTEM of *Alcyonium* can only be demonstrated in sections that have been specially prepared. It consists of a few minute star-like cells situated in the mesogloea close to the endoderm and ectoderm layers of the polyps, connected together by very fine anastomosing nerve fibrils.

MESOGLOEA.—The substance of the mesogloea is, according to Brown, chiefly composed of a Hyalogen. Previous to the conversion of the Hyalogen into Hyalin it yields a Mucin. It does not contain Gelatine, and consequently to speak of it as a gelatinous structure is liable to misinterpretation.

SEXUAL ORGANS.—In the month of April several mesenteries bear close to their free borders little groups of cells derived from the endoderm. These cells give rise to the sexual cells, and at this stage the sexes cannot be distinguished. Later in the year the groups of cells become differentiated. In the females the protoplasm of the cells composing a group fuses into a common mass, the nuclei diminish in number, and at length there remains only one large spherical cell with one nucleus (See Pl. III., fig. 19). This cell is a young ovum. It grows very slowly in size, and spherical globules of some kind of fatty food material which we may call yolk, appear in its cell substance. The only other changes that take place during the last six months of the year are the appearance of a yellowish red pigment at the periphery and, in the last month, the transit of the large nucleus to one side of the ovum (Plate II., fig. 13). In the males the group of primary sexual cells that are formed on the mesenteries in the spring undergo rapid cell division, and a spermary is thus formed, packed with very minute cells. The protoplasm of these cells is so tightly pressed together that the spermary has the appearance of being a single cell, with an enormous number of nuclei. When the spermary is about 0·1 mm. in diameter, the cells collect towards the periphery, leaving a rounded space containing strands and lumps of protoplasm (Plate II., fig. 14). This central body may correspond with the "blastophore," which occurs in the spermatogenesis of some other animals. The ripe spermatozoa which are only found in December completely fill the cavity of the spermary. They consist of a head with a cone-shaped anterior end, followed by a spherical body, and a long flexible tail.

Development.

When the ova are ripe, they are about 0·5 mm. in diameter, and they are discharged into the water by way of the mouth the stomodaeum distending considerably to allow them to pass. If we may judge from what may be seen in an aquarium, the spawning is a very lengthy process, as each ovum takes at least ten minutes to pass through the stomodaeum. At any rate, they do not appear to be "vomited forth in great masses," as they are in *Renilla*, according to Wilson.

The early stages of development are probably very variable as regards the external signs of segmentation.

It is certainly the case, however, that some young embryos which appear to be unsegmented when examined whole with a simple lens are found, in sections, to be more advanced than others which are clearly segmented. It is really quite impossible to say, in the present state of our knowledge, what is the "normal" or "typical" proceeding at this early stage. There is a stage, however, occurring a few hours after fertilisation, in which the embryo consists of a single mass of protoplasm containing several protoplasmic "islands" almost free from yolk in each of which there is a nucleus (Pl. III., fig. 16). It is really a "morula" stage, although it may or may not exhibit mulberry markings externally. The "islands" of protoplasm and their nuclei increase rapidly in number, and soon the outlines marking the boundaries of the cells become clearly differentiated. The nucleus of the cells in these stages divides by a well-defined karyokinesis (fig. 17), several beautiful achromatic spindles with their chromosomes being seen in sections of every well-preserved embryo that is examined. A cavity makes its appearance in the interior of the mass of cells constituting the embryo and at the same time the cells at the circumference become arranged in a definite row.

In the next stage (fig. 18) a definite ectoderm is formed at the periphery. This layer differs from the layer of embryonal cells of the last stage in the fact that it is clear and devoid of yolk globules and that the cells are ciliated. Inside the ectoderm there is still a layer of undifferentiated embryonal tissue, laden with yolk, enclosing an irregular cavity.

Later stages than this of the larval development have not yet been discovered, and it is not known how the stomodæum and mesenteries are formed. It is probable, however, that soon after the mouth is formed the larva settles down on a rock or shell at the bottom, loses its cilia and assumes the characters of a single Alcyonarian polyp. The youngest stage that the author has seen after fixation is shown on Plate III., fig. 24. In this case the primary polyp has already formed one secondary polyp by gemmation.

Physiology.

When the polyps of an *Alcyonium* are fully expanded they are in a state of physiological activity, the muscles are constantly contracting, the cilia vibrating, and other functions of the body being performed. This functional activity does not go on continuously, but at times the anthocodiæ are all retracted, and a period of rest supervenes. There can be little doubt that the period of rest occurs rhythmically, the rhythm corresponding not with the light and darkness of day and night, but with the high and low tides. As a result of some experiments that were made a few years ago, it seems probable that *Alcyonium* rests regularly at every low tide, that is to say, twice in every day and night, but owing to the unsatisfactory conditions appertaining to life in a sea-water aquarium, it is not possible to state how long the periods of rest last in natural healthy surroundings.

Circulation.—It is certain that in such a fleshy mass as a colony of *Alcyonium* presents, a free circulation of a liquid throughout the whole system is absolutely necessary for the respiration of the tissues. In the absence of any rhythmically contractile organ which could be called a heart, how is this circulation maintained? The answer is, entirely by ciliary action. When the polyps are expanded, a current of water is produced by the constant vibration of the long cilia of the siphonoglyph, which flows from the mouth downwards into the coelenteric cavities. It is probable that some of the fresh sea-water thus inhaled is driven by vortices created by the cilia of the endoderm into the canals of the mesogloea, and thus the rapidly growing parts of the colony are supplied with oxygenated water. The remainder travels down the ventral sides of the coelenteric cavities. A current of water in the opposite direction is produced by the cilia of the long dorsal mesenterial filaments (see Plate III., fig. 20 *Dmf.*) which probably makes its exit by way of the dorsal side of the stomodaeum. In this manner a regular circulation of the water in the colony is maintained during the time when the polyps are expanded.

Digestion.—Particles of food which are caught by the tentacles are, if suitable in size, passed to the mouth and rapidly swallowed by the stomodaeum. The stomodaeum in *Alcyonium* is not, as it is in *Xenia*, and some other Alcyonarians, a digestive tube. The food is unaltered during its passage through it. On passing the lower or inner opening of the stomodaeum the six ventral mesenterial filaments embrace it, and hold it fast for some time. During this time the glands on these mesenterial filaments secrete a digestive fluid, which partly dissolves it and breaks it up. The food which is thus dissolved is assimilated by the general endoderm lining the coelenteron, and possibly also by the ventral mesenterial filaments themselves. Food particles that escape from the embrace of the mesenterial filaments and particles of oil or fat which are not dissolved by the digestive ferment are swallowed by endoderm cells and digested intracellularly. The ferment of the digestive fluid secreted by the filaments is alkaline in most Coelenterates, and the ferment secreted by the endoderm cells into their food vacuoles is an acid ferment. From the few observations that have been made on *Alcyonium*, it is probable that in this respect it agrees with other Anthozoa.

The above description of the anatomy and development of *Alcyonium digitatum* is compiled entirely from my own observations. A considerable part of the work has already been published in a paper which appeared in the Quarterly Journal of Microscopical Science, Volume 37, and the reader may be referred to this for further information on the histology of the species. The account of the chemistry of the mesogloea was published in the same volume by Mr. Brown.

An important paper has recently been published by Mr. G. C. Bourne in the "Transactions of the Linnæan Society," Vol. VII., pt. 10, on the genus *Lemnalia*, in which the term "Anthocodia," which has been adopted in this memoir, and others which will be useful to students of the Alcyonaria are introduced for the first time.

Explanation of the Plates.

Plate I.

Fig. 1. A small specimen of *Alcyonium digitatum*, L., natural size, killed in such a manner that some of the anthocodiæ (*i.e.*, polyp-heads) have remained expanded while the others are completely or wholly retracted. The anthocodiæ on the knob seen at the right hand side of the drawing, for example, are retracted, and the star-like depressions indicating their positions are the "false mouths," as explained in the text. This figure is drawn from a specimen taken at Port Erin.

Fig. 2. Another specimen of *Alcyonium digitatum* drawn in outline and reduced about $\frac{1}{3}$ diam. to show the blunt lobe-like processes that are

frequently formed in the older colonies. This figure is drawn from a specimen in the Cambridge Museum.

Fig. 3. Vertical section through a portion of a colony (semi-diagrammatic) to show the anthocodia in different stages of retraction, the different sizes of the polyps, the general arrangement of the canal system, the position of the spicules, &c. The mesenterial filaments are represented as being in the same plane as the tentacles, which they are not, in order to illustrate certain points in their relations. The following points are illustrated in this figure: 1′ represents the fully - expanded anthocodia of a polyp, 2′ represents a partially retracted anthocodia in which the tentacles are contracted and folded inwards towards the mouth, the body-wall forms a circular fold over the crown of tentacles, 3′ represents an anthocodia in which the tentacles and stomodaeum have sunk to the level of the general surface of the colony, 4′ an anthocodia which has sunk below the surface, and 5′ an anthocodia completely retracted, the false mouth having closed. It will be noticed that the long (dorsal) mesenterial filaments are represented as being all on the left side of the polyps. This indicates that the axis of the lobe from which the section was made was on the left side of the drawing.

Fig. 4. A fully-expanded anthocodia drawn from a living specimen at Plymouth. The bases of the tentacles are extended in a bullate

fashion, and the pinnules are somewhat contracted. The stomodaeum (*St.*) and the six short and two long mesenterial filaments may be seen through the transparent body-wall. At the base of the crown of tentacles, and at the region where the anthocodia abuts on the general surface of the colony the body-wall is rather more opaque owing to the presence of several spicules.

Fig. 5. A diagram of a section through a portion of a lobe, to show the mode of communication between the polyp cavities in the inner parts of the colony.

Plate II.

Fig. 6. Transverse section through an expanded anthocodia in the region of the stomodaeum, showing the siphonoglyph (*Si.*), the folded epithelium on the rest of the stomodaeum (*St.*) the arrangement of the retractor muscles (*Msc.*) on the mesenteries, and the structure of the body-wall. *Ect.* = Ectoderm. *Mes.* = Mesogloea, and *End.* = Endoderm.

Fig. 7. A series of stages of the final development of the spermatozoa as seen in a preparation made by breaking open a spermary in December. *a.* a ripe spermatozoon, *b. c. d.* and *e* stages in the formation of the tail, *f.* a cell with four nuclei occasionally met with in these preparations.

Fig. 8. A cnidoblast, containing an immature nematocyst.

Fig. 9. A mature nematocyst.

Figs. 10 and 11. Two nematocysts after their discharge.

Fig. 12. Two endodermal myo-epithelial cells.

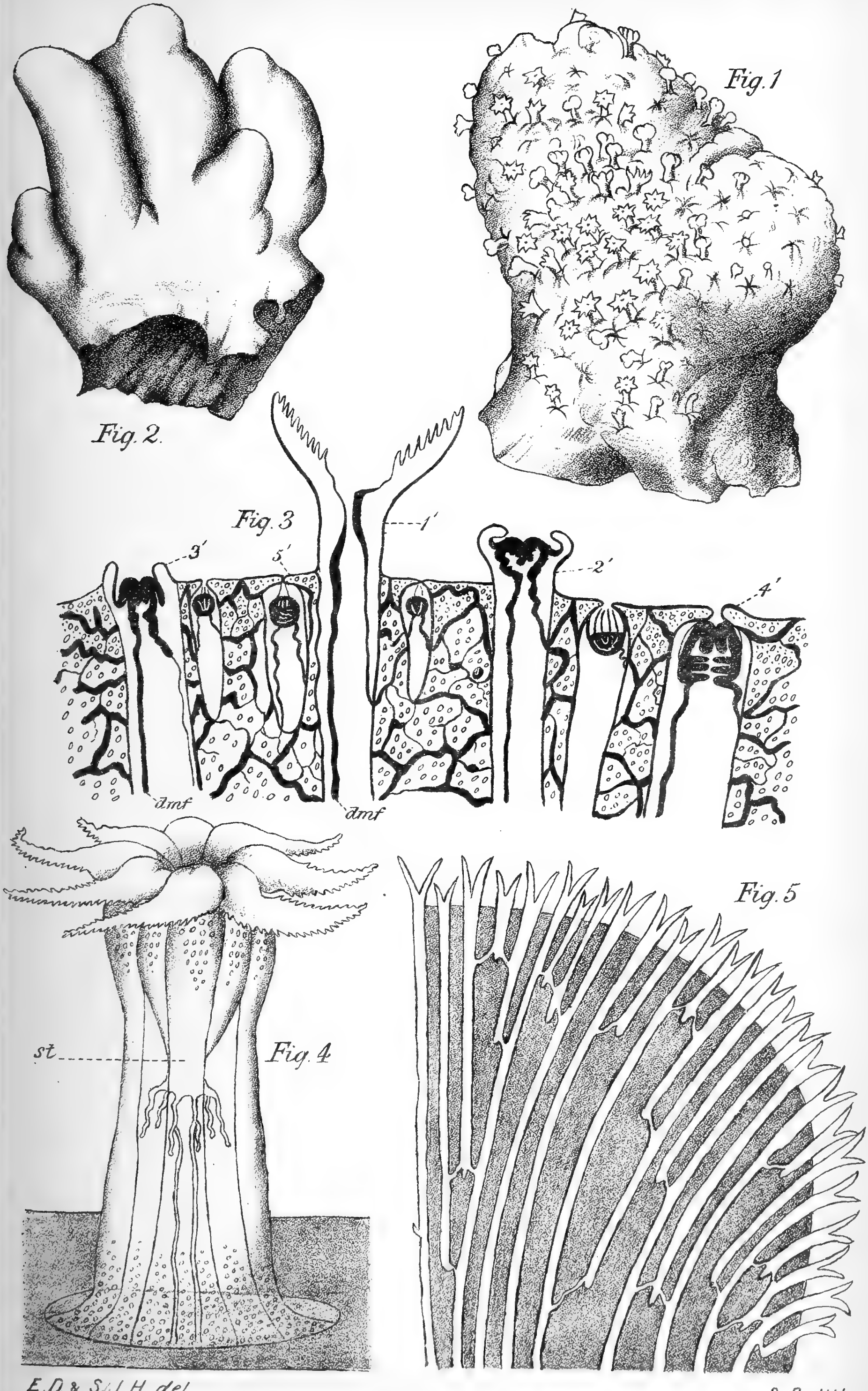
Fig. 13. Section through an ovum early in December, showing the large germinal vesicle close to the periphery and the single large germinal spot which it contains.

Fig. 14. Section through a spermary in the autumn, showing the endodermal capsule which covers it, the central (*bl.*) protoplasmic mass (blastophor) in the centre, and the densely crowded nuclei in the periphery.

Fig. 15. Diagrammatic vertical section through an anthocodia. *Si.* the siphonoglyph on the ventral side of the stomodaeum. *Vmf.* a ventral mesenterial filament. *Mst.* a ventral mesentery. *R.Msc.* retractor muscle. *T.* tentacle. *Gon.* Gonad, and the other letterings as in Fig. 6.

Plate III.

Figs. 16, 17, 18. Three stages in the development of *Alcyonium*, as seen in transverse section. Fig. 16, the morula stage of eight cells, the nuclei of three of these cells can be seen in a star-shaped island of clear protoplasm, the remainder of each cell is filled with closely crowded globules of yolk, which are not represented in the drawing. Fig. 17. A later stage in which a space has appeared in the centre of the embryo, but the cells are still undifferentiated. Fig. 18. A planula stage, in which the archenteric space is much larger, the ectoderm is fully differentiated and ciliated, and the endoderm a continuous



E.D. & S.J.H. del. S.B. lith.

ALCYONIUM.

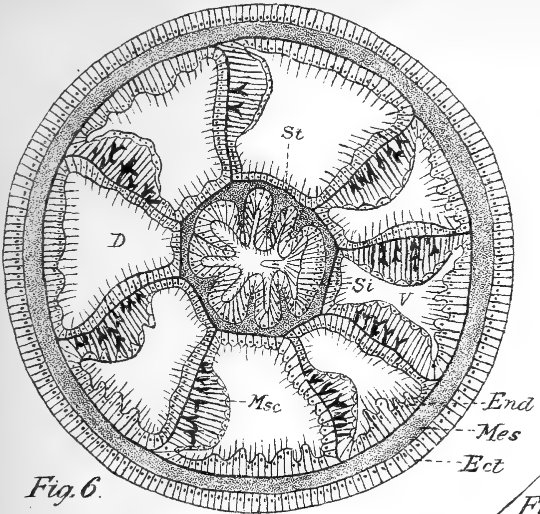


Fig. 6.

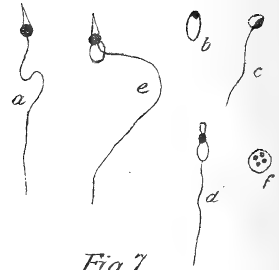


Fig. 7.

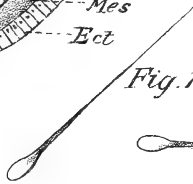


Fig. 10

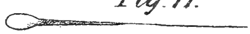


Fig. 11.

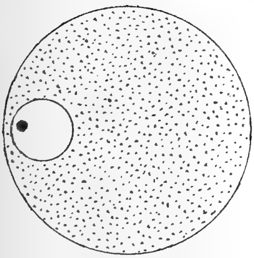


Fig. 13


Fig. 8


Fig. 9

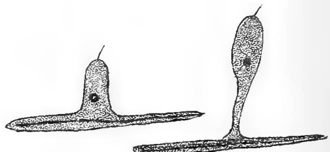


Fig. 12

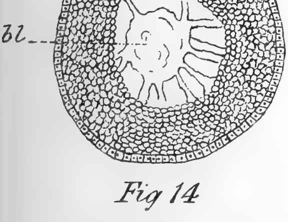


Fig 14

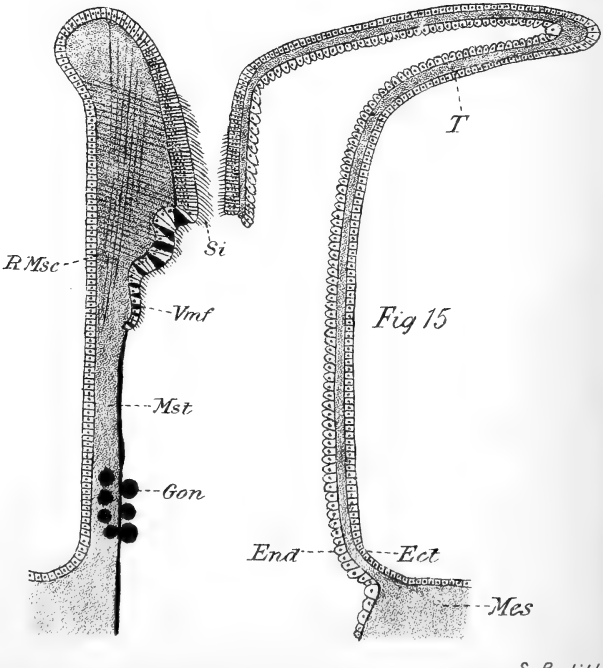


Fig 15

E.D. & S.J.H. del.

ALCYONIUM.

S. B. lith

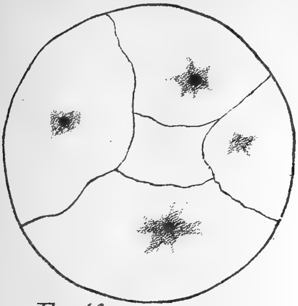


Fig. 16

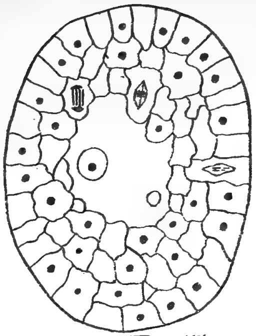


Fig. 17

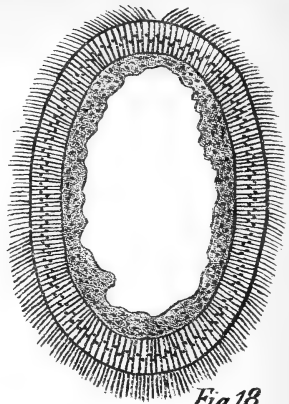


Fig 18

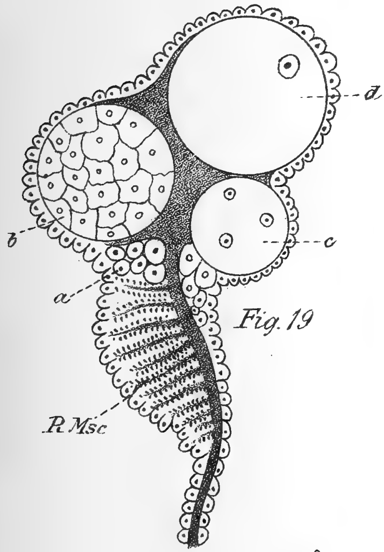


Fig. 19

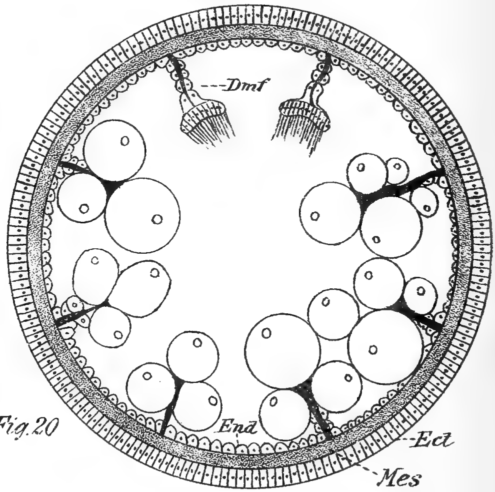


Fig. 20

Fig. 21

Fig. 22

Fig. 23

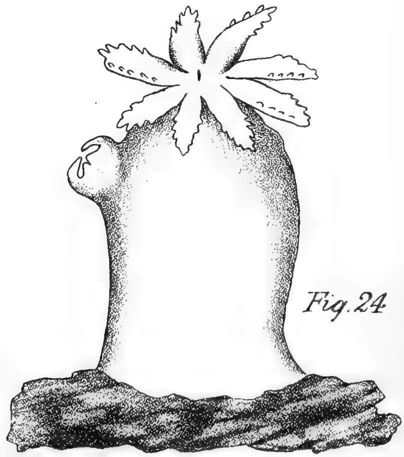


Fig. 24

S. J. H. del.

S. B. lith.

ALCYONIUM.

nucleated syncytium undifferentiated into endoderm cells.

Fig. 19. A section through a ventral mesentery in the summer, showing the manner in which ova are formed. *a.* A clump of endoderm cells sinking below the surface. *b.* A nest of young egg-mother cells. *c.* A stage in which the protoplasm of the cells composing a nest has fused into a single mass, and the number of nuclei is reduced considerably. *d.* Last stage in which only one nucleus, the germinal vesicle of the ovum, remains and the ovum has begun to increase in size. The retractor muscles *R. Msc.* of the mesentery are here seen in transverse section.

Fig. 20. Transverse section of an anthocodia in the region of the gonads, showing the six mesenteries bearing ova and the two (dorsal) mesenteries which are barren, *Dmf.*

Figs. 21, 22, 23. Three types of spicules met with in *Alcyonium.*

Fig. 24. The youngest stage of colony formation that has been found by the author.

SOME VARIATIONS in the SPINAL NERVES of the FROG, with a NOTE on an ABNORMAL VERTEBRAL COLUMN.

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

With Plates I. and II.

[Read Dec. 14, 1900].

The subject of variation is one which is unexpectedly and often unpleasantly brought home to the mind of every demonstrator of Zoology at the outset of his career. As two classic instances of what Bateson calls *meristic variation* may be cited the so-called "spinal nerves" of the Frog, and the apertures of the reproductive ducts in *Nephrops norvegicus.* With regard to the former, it happens not infrequently that the tenth or coccygeal nerve is *apparently* absent, whereas the fact is that the sciatic plexus is, as I consider, "postfixed," the tenth spinal nerve shows a considerable abnormal increase in bulk, and completely goes over into the Nervus ischiadicus, instead of only partially doing so, or not doing so at all. In these cases the seventh spinal nerve does not as a rule contribute any fibres to the sciatic plexus. And with regard to *Nephrops*, abnormalities in the oviducal and spermatic apertures are by no means uncommon, and I remember examining three specimens, *two* of which were abnormal, and had *four* supernumerary spermatic apertures between them, occurring as follows:

A			B	
		Third walking leg	●	
●	●	Fourth ,,	●	
●	●	Fifth ,,	●	●

In *Astacus fluviatilis*, on the other hand, although anatomically very similar, variations in these apertures are comparatively rare, Bateson* only finding 23 variations in 586 females and one variation in 714 males. In the Frog, variations in the *RR. ventrales longi* of those nerves contributing to the brachial and sciatic plexuses are so common and often so considerable that one sometimes positively hesitates before committing oneself as to what the exact normal is. Thus the brachial plexus is normally constituted by the second "spinal" + portions of the first and third. But how often is the first entirely independent, and who would care to state definitely, without an elaborate statistical investigation, how often the third should contribute to the plexus—partially and obviously, wholly and invisibly, or not at all? Again, what extensive variations are there to be found in the *ensemble* of the sympathetic system, where, for example, the coccygeal ganglia may, according to Wiedersheim, vary in number from one to twelve!

The present paper contains a description of three cases of variation in the spinal nerves of the Frog, all of which are, in my experience, of a very uncommon character, and do not fall between the extremes of average variation. In two of these cases I am indebted to my friend Dr. John Beard for the material, and he has, with characteristic generosity, allowed me to dissect and describe it. It must, however, be emphasized that any macroscopic investigation of a subject such as this can have only a very limited scientific value, as the path of a nerve fibre has an interest altogether subordinate to its exact central origin and peripheral distribution. Hence no investigation of the peripheral nervous system can be considered complete, or even trustworthy, unless checked

* "Variation," pp. 153 and 154.

by, or conducted according to, the findings of the component theory.* The "Spinal nerves" of the frog are in this paper enumerated from before backwards, the hypoglossal, according to English custom, being considered the first. I am, of course, aware that this nerve is morphologically the second, the first or *N. suboccipitalis*, present in the tailed amphibians, as shown by Fürbringer, occurring only in the embryo, according to Chiarugi.

In the first case, a specimen of *Rana temporaria*, the brachial plexus is normal enough on the right side, according to Gaupp's scheme, but on the left side the third nerve communicates in the very unusual way shown in the figure. Nerves iv., v. and vi. are quite normal, but the sciatic plexus is in a somewhat unique condition. The presence of what I have identified as two iliohypogastric nerves on the left side and of two crural nerves on the right side may be noticed at once. That these nerves may be duplicated has already been noticed by Miss Sweet in *Hyla aurea*. The chief interest in the specimen however lies in the condition of its coccygeal nerve, which is very much larger than usual, and instead of only more or less indirectly contributing towards the sciatic plexus, passes wholly into it without the exception of a single fibre. Where the accessory coccygeal fibres come from, and how the fibres in the different factors of the plexus had been shuffled to produce this arrangement, could of course only be determined by serial sections. The ixth nerve, it will be noted, forms a loop before uniting with the plexus. This variation may be explained in two ways. We know from the admirable work of Adolphi that larval Anura, on metamorphosis, lose a number of caudal spinal nerves. That is to say, when the vertebral axis shortens up from behind forwards

* Cf. C. J. Herrick, Jour. Comp. Neurol. ix., 163 *et seq.*

to produce the complex known as the urostyle, several of the most posterior spinal nerves are eliminated in the process. The condition of the nerves of this specimen may, therefore, be a reversion to an ancestral condition, before the coccygeal nerve became reduced to its present subordinate function. Or, as to me seems more probable, the sciatic plexus is becoming postfixed, and is incorporating the coccygeal nerve instead of dropping it, as Adolphi and Miss Sweet contend. The postfixation of the sciatic plexus is also borne out by the condition of one of the other two frogs now described, in which the plexus also exhibits a backward movement. It must be borne in mind, however, that Adolphi and Miss Sweet have arrived at an entirely opposite conclusion, but their statistical method appears to me to be open to some objection, especially in the light of recent work on the number of fibres in the Frog's spinal nerves.

The second case, a *R. esculenta*, illustrates the compound nature of the urostyle. On the left side the brachial plexus is not quite normal, and on the right side the sixth nerve was missing. This may have been removed by the student before the specimen came into my hands, but there were no obvious signs that it had ever existed. The nerves vii., viii., ix. and x. are in all essential respects the same as in the previous specimen, that is to say, the coccygeal nerve is much larger than usual, and passes over entirely, with the exception of a small bundle of fibres as shown in the figure, into the sciatic plexus. In addition to these, however, an eleventh nerve is present, emerging from the urostyle at about the posterior extremity of its anterior third. The vertebral column was quite normal, and the urostyle did not appreciably differ from what may be considered its normal relative length. The extra nerve was very small, and was not connected in any way with the sciatic plexus. It will be noted that in this case also the latter plexus is postfixed, and that the urostyle is a morphological compound of at least three pieces.* On the left side the ixth nerve was the stoutest, the others following in the order, 8, 10, 7. On the right side, the nerves, similarly arranged, would read, 9, 10, 8, 7. The right xith nerve was appreciably smaller than the left, and the left crural was stronger than the right. In *Hyla aurea* Miss Sweet found an xith nerve in 3·2 per cent. of 125 specimens examined, whilst in *Pipa* Fürbringer has shown that two pairs of spinal nerves normally perforate the urostyle.

The third case, also a *R. esculenta*, is complicated by the occurrence of an abnormality in the vertebral column, thus rendering the enumeration of the nerves a subject for speculation. Unhappily one side of the specimen had been too much damaged to be described here, although it was apparently similar to the side figured. The first point noticeable is that the nerve VI + takes no part in the formation of the lumbo-sacral plexus, and that the relative position of this plexus with regard to the urostyle is quite normal, so that it has apparently dropped a nerve in front without picking up one behind. But there is a nerve present (viii.) which perforates the arch of the compound sacrum, and bears the same relation to the plexus as a normal viiith nerve. It therefore becomes necessary to describe the sacrum.

That the vertebra labelled 7 *may be* the eighth is suggested by the fact that it is amphicoelous, and only the eighth vertebra of the frog exhibits that character. The urostyle is further no more or less than its normal

* It must not be forgotten that in *Bombinator*, according to Götte, the urostyle represents 3 fused vertebrae—x., xi. and xii. Cf. also the condition in *Discoglossus*.

relative length, and has therefore not contributed to the abnormality of the sacrum. This, seen from below, has an undivided centrum almost double the normal length of a single vertebra, and dissection shows that it has two transverse processes on each side, both of which on the left side support the ilium, and thus form a compound sacrum, but on the right side the posterior one only doing so. The neural arch is perforated by conspicuous foramina which transmit the large nerve labelled viii. in fig. 3. Above, there is a small but obvious single neural spine, and immediately behind this is a deep transverse trench, at the bottom of which is a narrow fissure partially separating the arch into anterior and posterior portions. Behind this trench the arch shelves sharply down to the neural canal. This vertebra, peculiar as it is, so very closely resembles another sacrum described by Howes, that the above description and figure IV. should be compared with his (No. 15, p. 269). There is this *apparent* exception, however—that in Howes' case the compound represented the true 8th and 9th vertebræ, whilst mine is of a 9th and an extra vertebra.

The question now arises, how are the extra nerve and vertebra to be enumerated—for it must be admitted that the last vertebra is really a compound of two—there being a duplicate transverse process, neural arch and nerve. Taking Gaupp's figure (No. 10, p. 165) of the spinal nerves as a standard, it is at first somewhat surprising to note that the whole lumbo-sacral plexus and the coccygeal nerve are perfectly normal, except that the viiith nerve in my specimen does not apparently contribute any fibres to the *N. cruralis.* As the urostyle and its nerves are quite normal, and as in addition to the urostyle we have a vertebral column of ten vertebræ and an extra nerve, it is obvious that a vertebra and a nerve have been intercalated somewhere.* Impressed by the amphicoelous centrum of the vertebra labelled 7 in fig. 3, I was at first inclined to believe that the extra vertebra must be either 8 or 9. But this view involved such confusion in homologising the "spinal nerves" that it had to be abandoned. But if we suppose that the intercalated vertebra is 6+ and the intercalated nerve vi+, all difficulties at once vanish, and the result is a frog absolutely normal in its nerves, and only exhibiting an abnormality in its vertebral column for which we have many parallels. I therefore adopt this view on the following grounds:—

1. The nerve vi + does not, as it should, enter into the lumbo-sacral plexus. There are thus five *NN.* abdominales instead of four, and the distribution of these shows the extra one to be that labelled vi +.

2. The fact that the vertebra numbered 7 is amphicoelous does not *necessarily* prove that it is the morphological eighth.† It shows that the amphicoelous vertebra should be the penultimate one, and the vertebra 7 *is* the physiological (though not the morphological) penultimate vertebra, since 8 and 9 are immovably fused.

3. The lumbo-sacral plexus is absolutely normal, both in its formation, branches and distribution, whereas if one of its factors had been an intercalated nerve, we are entitled to expect that it would have had some appreciable effect on the plexus.

4. Howes has described in a normal nine vertebra frog

* I must not be understood, when the term "intercalation" is used, to imply that the intercalated structure is a neomorph, as Baur believes. My position is rather that of G. H. Parker (No. 18).

† Lloyd Morgan (No. 17) describes two eighth vertebræ of *R. temporaria* as not being amphicoelous, and mentions that he has seen this abnormality before.

an incomplete fusion of the last two vertebræ (8 and 9), so resembling my vertebræ 8 and 9 as to strongly suggest that the two latter are morphologically the eighth and ninth vertebræ of the animal. Compare also Lloyd Morgan, No. 17, and Howes, Nos. 14 and 15. Parallels in *Palæobatrachus* and other Amphibia are to be found in the works of Boulenger, Camerano, Walterstorff, and Adolphi.

5. The urostyle is precluded from having taken any part in the abnormality of the vertebral column by the fact that its relative length is normal, and the last two nerves are related to it precisely as in Gaupp's scheme of the normal "spinal nerves."

Finally, the explanation above is the most simple, and involves less theory than any other hypothesis.

The most important works bearing directly on variations in the spinal nerves of frogs and toads are those by Adolphi, Miss Sweet, and Braun. With regard to the two former, I may be allowed to express some dissent from the method of their statistical investigations. These are based practically on variations in the size ("Dicke," "Thickness") of the nerves forming the plexuses. Now, if the size of a nerve had any individuality, that is to say, if it were any criterion of, or index to, the size and number of its fibres, the method would be beyond cavil. But we know from recent work that the size of a nerve is often not constant, nor can it, without investigation, be taken as indicating the *true bulk* of the nerve, *i.e.*, the number and size of its fibres. It is conceivable that the frog may be exceptional in this, but the conclusions of Adolphi and Miss Sweet can, it seems to me, only be accepted with reservation until their methods have been tested. The former regards both the brachial and lumbosacral plexuses to be moving forward, whilst the latter admits this for one plexus, but not for the other. In particular I would draw attention to Miss Sweet's fig. 2 (p. 282), drawn up to show the transference of the cruralis fibres from the ixth to the viiith nerve, a series which I think, does not appear to be a very natural one, or to support the method on which it is based. The works of these two authors have cleared up so many points that I have ventured to draw attention to what appears to me this one defect in their work.

I am greatly indebted to my valued friend, Mr. A. W. Kappel, Librarian to the Linnean Society, and also to Prof. G. B. Howes, F.R.S., for help with the literature.

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* Papers marked with an asterisk I was not able to consult at the time of writing.

† *Lumbo*-sacral *plexus* or *plexuses* is evidently intended.

Explanation of the Figures.

Fig. 1. Dissection of *R. temporaria* from below, to show abnormal configuration of the Rami ventrales longi of the spinal nerves. *1—9*, the centra of the vertebræ; i.—x., the R.R. ventrales longi of the ten spinal nerves; *N.Br.*, Nervus brachialis; *N. Coc.*, N. coccygeus; *N. Co. Cl.*, N. coracoclavicularis; *NN. Cr.*, Nervi crurales; *N.Hy.*, N. hypoglossus; *NN. Il. Hy.*, NN. iliohypogastrici; *N.Sc.*, Sciatic nerve (N. ischiadicus); *Ur.*, Urostyle. X 2.

Fig. 2. Similar dissection of a *R. esculenta*, vi. ?, missing sixth nerve; xi., extra or eleventh nerve. Other letters as before. X 2.

Fig. I.

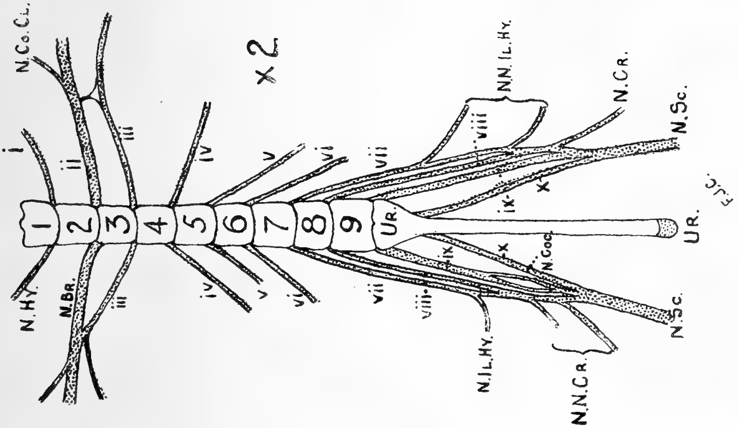
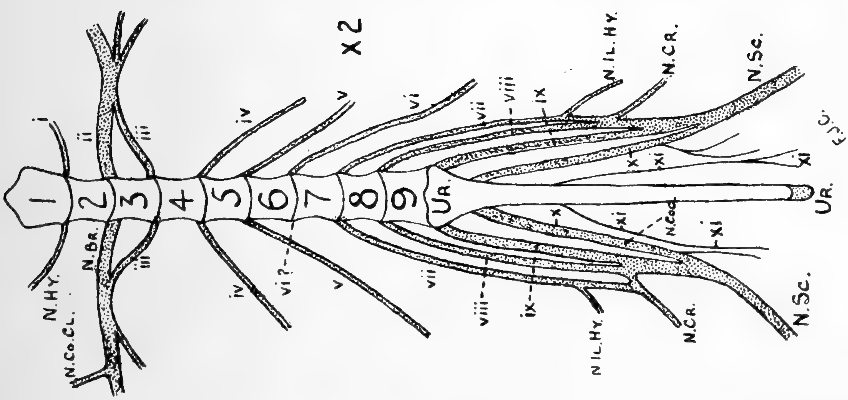


Fig. II.



SPINAL NERVES FROG.

Fig. III.

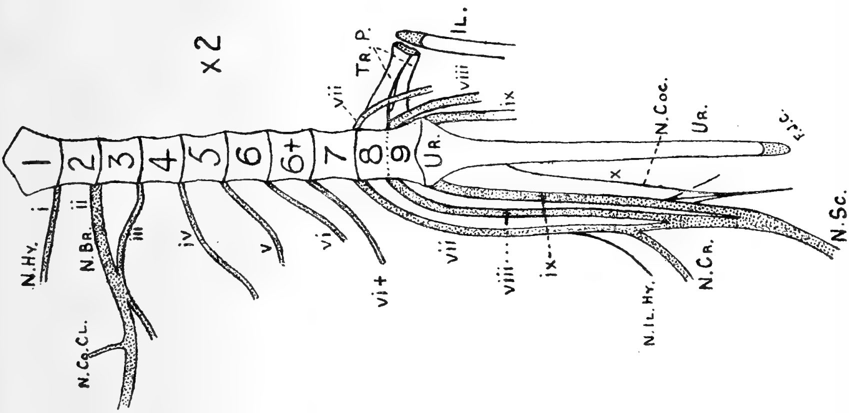
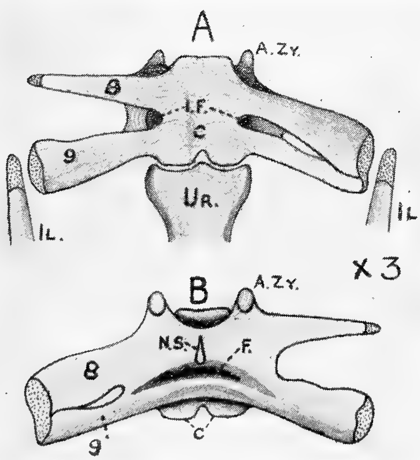


Fig. IV.



SPINAL NERVES FROG.

Fig. 3. Same dissection of a *R. esculenta*; 6+, an extra vertebra; vi.+, its corresponding nerve; *Tr. P.*, transverse processes of the compound sacrum (vertebræ 8 and 9); *Il.*, ilium. Other letters as before. X 2.

Fig. 4. Dorsal and ventral views of the compound sacrum of the third specimen (cf. fig. 3). A. ventral view; B. dorsal view. *A. zy.*, anterior zygapophysis; *C.*, centrum; *F.*, fissure imperfectly separating the neural arch of the sacrum into two; *I. F.*, intervertebral foramina transmitting the viiith nerve; Il., Ilium; *N.S.*, neural spine; *Ur.*, urostyle; *8* and *9*, transverse processes of the compound sacrum. X 3.

Report on the Investigations carried on during 1900 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, Resident Fisheries Assistant at Piel, and Mr. James Johnstone, B.Sc., Fisheries Assistant at Liverpool.

With Nine Plates, and other Illustrations.

Contents.

Introduction and General Account of the Work.

In the main the work of the past year has been similar in its nature to that of the previous one, and has consisted in:—

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

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

(3) Certain observations at sea taken from the steamer, at Piel, at the Isle-of-Man, and at various other points in the district, by Mr. Dawson, Mr. Ascroft, and others—all discussed and reduced to order at the Liverpool Laboratory;

(4) The work of the circulating Fisheries Exhibit;

(5) Practical laboratory classes at University College, Liverpool, for fishermen; and

(6) Various memoranda and reports that I have had occasion to address to the Chairman and Committee during the year.

I shall remark upon some of these matters here, and the others will be treated more fully in the separate sections which follow. Last year I commenced the plan, which I hope to be able to adhere to, of having in each annual report a detailed account of some animal of local economic importance. It was then a memoir on the common Cockle, by Mr. Johnstone; this time it is a full account of two closely allied and very important Fish-Parasites, *Lernœa* and *Lepeophtheirus*, by Mr. Scott; while next year it will be the memoir on the Plaice by Mr. Cole and Mr. Johnstone, for which the plates are already drawn. Mr. Scott's remarks upon the effect which the fish-parasites have on their hosts, and upon their nutrition and mode of life, will be found of interest. The preparation of this account of the fish-parasites has occupied a large portion of Mr. Scott's time during that period of the year when hatching operations were not in progress.

An account of the hatching work will be found at p. 31. The plan of storing up spawning fish* in the tanks in place of trusting to the steamer for supplies has been most successful, and the increase from the three and a half millions of the previous year to fourteen millions of young fish set free this year is most satisfactory. For the rest, Mr. Scott's time has been filled up by collecting and observing, by giving demonstrations to parties of fishermen, by experiments with shellfish, and by various other pieces of useful work. The determination of the spawn-

* We had over 100 adult flounders in the tanks. I see from the Report of the Scottish Sea Fishery Board that in their first year's work at their new hatchery at Aberdeen they had 400 spawning plaice, from which over 16 millions of fry were hatched. The female flounder, however, produces about three times as many eggs as the plaice.

ing times and the habits of the mussel at Piel will be found on p. 161.

Mr. Johnstone's time—in addition to helping me with general work, correspondence, the examination of any specimens that arrive, the preparation of "memoranda" throughout the year, and of this Report—has been largely taken up with arranging and superintending the removal of the travelling Fisheries Exhibit from place to place. The packing and unpacking of specimens, the renewal of labels, &c., takes up a good deal of the time of both Mr. Johnstone and of the fisheries laboratory boy, W. Raw.

The Exhibit, it will be remembered, after being at Liverpool, Salford, Preston and Bolton, was at University College in the winter of 1899-1900. In March it was removed to St. Helens, where it remained at the Public Museum till November. The Curator, Mr. Alfred Lancaster, has sent me a letter on behalf of his Museum Committee, tendering their thanks to the Lancashire Sea-Fisheries Committee for the loan of "the very interesting and instructive collection of Sea-Fisheries Exhibits." He states further that "the exhibition was visited by upwards of 16,000 persons," and he refers to the use which school teachers made of the exhibition as the subject of object lessons.

It will be remembered that a couple of years ago some desire was expressed to have the exhibit at Barrow, but negotiations eventually broke down. Mr. Scott has since suggested that if the cases were exhibited for a time in the large laboratory at Piel, that might serve for visitors from Barrow and from the neighbouring fishing villages. Accordingly in November the collection was transferred to Piel, and is now on exhibition there.*

* Any other Museums or public Institutions desiring to have the Fisheries Exhibit on loan should apply for a copy of the conditions and regulations.

During the past year the following have occupied work places in the laboratory at Piel for the purpose of carrying on Zoological investigations:—

Dr. F. W. Gamble, Owens College, Manchester.
Working at Crustacea.

Dr. J. T. Jenkins, University College, Liverpool.
Working at digestive glands of Oyster.

Mr. F. H. Smith, B.Sc., Barrow-in-Furness.
Working at Algæ and Diatoms.

Mr. J. E. Turner, B.A., Barrow-in-Furness.
Working at Marine Zoology and Fisheries.

Mr. John Graham, B.Sc., Barrow-in-Furness.
Working at Marine Biology and Physics.

These gentlemen have sent me short reports upon their work, in which they express their thanks to the Committee and their appreciation of the facilities given by the institution and the help rendered by Mr. Scott.

Parties of fishermen from Bardsea and Baicliff have been brought on various occasions by Rev. R. B. Billinge and Rev. Dr. Hayman, when explanations and demonstrations were given by Mr. Scott and Mr. Johnstone. Many other visitors, more or less connected with fisheries and scientific work, including Mr. A. Milman, C.B., Mr. J. B. Feilding, Mr. J. Fell and other members of the Sea-Fisheries Committee, and the members of the Barrow Field Naturalists' Club, have been shown over the establishment, and have had the operations explained to them.

I regret that the applications for the two £60 Scholarships for higher education in Fisheries Science, each tenable for two years at University College, Liverpool, which had been offered by the Lancashire County Council, were most unsatisfactory. Only one candidate applied, and from his defective preliminary education he was evidently quite unsuitable. This unfortunate result was apparently due to want of information among the higher schools in the county of the advantages to be derived from these scholarships. Several suitable candidates were heard of when it was too late. Considering the increase of work and of interest in Marine Biology and its application to Fishery questions of late years, it will be very unfortunate if this important experiment is allowed to lapse merely because of the absence of candidates in the first year, before the scheme was sufficiently known.

In addition to these scholarships, the County Council granted last year a sum of £100 for studentships to enable fishermen to undertake a short course of practical instruction in the Zoological Department at University College, Liverpool. It was, after careful consideration by a Committee, decided to send 20 elected fishermen representative of different centres and branches of industry, to University College; each to have a fortnight's instruction, and the sum of £5 to be paid to each man to cover his travelling expenses and board and lodging, and to reimburse him to some extent for what he might have lost by not following his ordinary vocation during the two weeks. These laboratory classes were held in February and March, 1900; and the main part of the work was carried on by Mr. Johnstone under my personal direction and supervision. The course was divided up into ten days, the work upon which was as shown in the following sections:—

1. The Common Mussel.—Structure (especially in regard to feeding, breathing, reproducing and habits), spawning and life-history.
2. Haddock.—Structure, feeding, breathing, spawning, and life-history.
3. Crab, Prawn, Shrimp and Lobster.—Habits, food, eggs, reproduction and life-history.

4. Surface Life of Sea.—Townet gatherings, fish eggs, diatoms, copepoda.
5. Fisheries Museum.—An examination of the cases in the museum at University College.
6. Edible Mollusca.—Oyster, cockle and mussel.
7. Fish Parasites.—External and internal, and their hosts.
8. Fish Structure.—Cod—Also stages of growth and changes in reproductive organs.
9. Food of Fishes.—How to examine fishes' stomachs and determine principal food matters.
10. Eggs and Larval Stages of Fish.—How to distinguish them and where they are found. Also eggs of Shell-Fish and Crustacea.

The whole course was made entirely practical in character. Each man examined everything for himself. The course was preceded by an introductory address by myself, and I finished it with a short concluding lecture.

The Committee may like to have recorded here the list of those who attended this first laboratory class for fishermen. It is as follows:—

In February—

John Wright, Southport.
William Wright, Southport.
George Alexander, Morecambe.
Luke Woodhouse, Morecambe.

In March—

Walter Baxter, Morecambe.
Robert Gardner, Morecambe.
James Allan, Morecambe.
Thomas Wilson, Morecambe.
Edward Woodhouse, Morecambe.
John Wright, Southport.
Albert Robinson, Southport.

John Rigby, Southport.
R. Rimmer, Marshside.
R. Ball, Marshside.
W. Houldsworth, Marshside.
John Hardman, Lytham.
Thomas Clarkson, Jun., Lytham.
John Parkinson, Lytham.
Robert Wright, St. Annes.

Mr. Dawson has already reported as to the way in which the men appreciated these practical classes, and he has now written to me of the benefit which, in his opinion, the studentships were to the fishermen. He says: "From Morecambe, Lytham, St. Annes, and Southport and the district I have heard the work spoken of with praise, and how satisfied the men were. I have also had several enquiries as to when more classes would be held, as the men wanted to go to them." And again, "On all sides I am informed that the fishermen were most interested in the work, and that if any more studentships are offered the difficulty will be not to get men to go, but to choose from amongst the number of applicants."

In October some questions arose in regard to the condition of the Oysters on the bed at the mouth of the Ogwen River, near Bangor, so I arranged that Mr. Andrew Scott, from Piel, should visit the locality, take certain observations, and bring back samples of oysters, of deposits, of water and of microscopic food materials in the neighbourhood of the bed, for examination in the Liverpool Laboratory. Mr. Scott carried out his inspection on October 9th, along with Mr. Jones, the Head Bailiff of that division, and brought back material which I examined with him. The oysters are *Ostrea edulis* in various stages of growth (from one to three inches in diameter), and are evidently living and reproducing between tide-marks. Many were attached to stones. It is consequently a *natural* oyster-bed, but it is evident from the condition of the specimens examined that there is not sufficient food on the ground or in the water to constitute the locality a good fattening area. The bodies of the oysters were found to be very thin and in poor condition generally.

The bed is entirely covered at each tide, and only ebbs completely dry at low water of an eighteen-foot tide with favourable weather. The bottom is hard, being composed of gravel and shells, with some fine mud between. Samples from the ground and from the water showed that diatoms and other minute forms of life which are so necessary in the case of a flourishing oyster fishery were so few as to be almost absent. It is quite possible that during summer, at the breeding season, more microscopic food may be present—perhaps due in part to the river, and it is probable that the bed in favourable seasons forms a good enough spatting ground; but all the evidence before us shows that it is not a favourable locality for the rearing and fattening of oysters. Probably the best plan would be to use it as a place for the production of spat, from which a certain proportion of the young oysters should be transferred to other localities where they can be more satisfactorily nourished. I think it worth while to try whether it would not be possible by the judicious placing of tiles and other collectors, and by certain obstructions in the water channels over the bed, to largely increase the deposit of spat; and I should recommend that some of the half-grown oysters be removed to certain grounds in the neighbourhood of Piel, on the south and south-east sides of Foulney Island, which we know to be richly supplied with diatoms and the other necessary food, in order that their growth may be watched and compared with that of similar oysters left on the bed at Bangor.

I think it is a question whether the spat on the Ogwen bed is derived wholly from the old oysters in sight, or whether its source may not be individuals in deeper water somewhere in the neighbourhood. I propose to visit the bed myself during next spawning season in order to try to settle this and several other questions in connection with the reproduction and spatting of the oyster.

The further point has been raised that the Ogwen River oyster-bed may be liable to sewage contamination from the drains of Bangor. The observations made by Mr. Scott and the samples brought back by him, although not absolutely conclusive on this point, certainly suggest material of sewage origin, and it is difficult to believe that under certain conditions of wind and tide the bed can escape from pollution by the town drainage. However, this is a matter that may require further investigation, and in any case it does not affect the value of the locality for the production of spat and the rearing of young oysters which may be fattened elsewhere before being placed on the market. The whole question of the disposal of sewage and the pollution of our rivers, estuaries and sea shores is one that is in an unsatisfactory condition, and requires more careful consideration than it has yet received.

I desire to draw the attention of the Committee to some points in connection with the so-called "Bacterial treatment" of sewage (by coke filter beds or by septic tanks), which is now being adopted in various parts of the country. The recently published report to the London County Council by Professor Clowes and Dr. Houston shows that the effluent discharged after such treatment, although it may seem pure and have some objectionable features removed, contains practically all the bacteria found in the crude sewage.* From the public health point of view the clarified effluent apparently may be little if at all better than the original untreated sewage. Under these circumstances I would ask—is it not a very serious matter that such an effluent should be allowed to discharge anywhere in the neighbourhood of shell-fish beds, or where any fishery contaminations† could take place? I may also remark in passing that however pure such an effluent may look in mixing with the sea, bathers should be warned against its dangers. Another point with which we are not directly concerned at present, although it is of great interest to the scientific man, and may be of practical importance to the country, is whether enormous quantities of valuable fertilising materials which ought to be applied to the land are not now being wasted in the sea. We can leave the bathers to the sanitary authorities, the question of fertilisers is one for the chemist and the agriculturist; but we are directly concerned with the coast fisheries, and I would urge that the Committee, and all fisheries authorities, should give most careful consideration to the relations between shell-fish beds and any sewage effluents, whether "treated" or not.

Early in the year I asked Mr. Johnstone and Dr. J. T. Jenkins, who was at that time working in my laboratory at Fisheries subjects, to devote a certain amount of time in each week to a careful examination and classification of all our fisheries statistics (accumulated during eight or nine years), with a view to the drawing of any conclusions

* London County Council Bacterial Treatment of Crude Sewage. Third Report by Dr. Clowes and Dr. Houston, 1900.

† I am not alluding to the conditions in the Thames, which I do not know personally. It may be that no difficulty arises there. I am speaking of the question generally, as such effluents may be likely to increase around our coast, and will require careful attention.

which might be indicated. It has been a lengthy and troublesome piece of work, lasting most of the winter, and over a thousand sheets of statistics have been very carefully analysed. The results, I regret to say, are by no means commensurate with the labour that has been expended. For the majority of fishes and localities the statistics are so defective or so vitiated from one cause or another that we felt that no reliable conclusions could be drawn. In fact it was decided in the end that the only area in regard to which we had sufficiently detailed information was the shrimping area at the mouth of the Mersey. Hence the article on that area by Mr. Johnstone and Dr. Jenkins which I include in this Report (p. 164).

But it must not be thought that I regard the time and labour which these gentlemen have spent in trying in vain to draw conclusions from the remaining statistics as lost because they have deduced nothing which we are able to publish yet. Far from it: it has led to the very important conclusion that the system we have hitherto employed on the fisheries steamer and elsewhere in the district is really inadequate, that the statistics are not taken sufficiently often or with sufficient regularity, and are not taken with sufficient detail. If this discovery leads to the adoption of a better scheme (such as the one I suggest below, p. 149), and to its faithful performance in the future, the disappointment we have had in finding one after another of the series of statistics broken by unfortunate omissions* will be mitigated, and we may then hope that the next decade will be so traversed by

* Due to the circumstance that we have only one small steamer available for all the police and other administrative work of a large district, in addition to what I cannot but regard as of still greater importance—viz., the observational work on the condition and variations of the fisheries and their causes.

observations as to leave no doubt as to the conditions of fisheries and the progress of events.

I have spoken of the statistics as being incomplete and inadequate; but although they do not give us the information we expected, they are by no means useless. Every correct observation, and there are many thousands of such in our sheets, is of value even if it deals with isolated facts. It may give useful information which may be required at any time, and we hope that all these observations may fit in with our future records of facts, and so play their part eventually in the elucidation of important points.

Statistics obtained as the result of investigations made with regularity at fixed spots in accordance with a definite scheme are the more necessary since such very different conclusions have been drawn of late years from the commercial statistics as supplied by the Board of Trade. One of the most recently expressed of these is an article by Mr. Walter Garstang, entitled "The Impoverishment of the Sea," in which the conclusion is arrived at that the fish population is decreasing because although the total catch increases year by year, the take *per unit of catching power* diminishes. I do not quarrel with Mr. Garstang's conclusion, but the argument by which he arrives at it does not carry conviction. Except on ground where there is practically an unlimited number of fish, doubling the number of boats would surely not lead to doubling the catch, and consequently as the boats increased the *take per boat* would diminish to some extent without there being necessarily a permanent reduction of the fish population.

Turning to another important side of fisheries work, namely, experimental investigation, it is of interest to note that in the twenty-fifth Report of the United States

Commission of Fish and Fisheries, just published, Commissioner G. M. Bowers states, "Our leading fishery product, the oyster, worth about $14,000,000 annually, is readily susceptible of increase by methods of cultivation, and each season shows a larger proportion of the marketable output taken from planted grounds, thus insuring a permanent and increasing supply." He states further that while the natural supply of oysters is surely becoming exhausted, the areas of the sea-bottom which are being artificially cultivated are becoming more and more productive, and certain States which have adopted "advanced cultural methods" are "reaping important pecuniary returns."

Then again, "There is unmistakable evidence of an increased abundance of Cod in the inshore waters along the entire coast from Maine to New Jersey. This may, without hesitation, be attributed principally to the work of artificial propagation centering at the stations of the Commission at Gloucester and Woods Hole."

The Commissioner urges that new work should be undertaken for increasing the lobster supply by artificial propagation. He states:—"During the past five years over 500,000,000 young lobsters have been artificially hatched by the Commission and planted on the East Coast. As practically all the eggs from which these were produced would have been destroyed had not the Commission purchased the egg-bearing adults from the fishermen, it can hardly be doubted that these operations have had a decided influence on the supply, but they have not as yet seemed to arrest the decline, in the face of overfishing and the destruction of short lobsters and brood lobsters carrying eggs." I have had an interesting letter from Professor H. C. Bumpus, who has charge of the work at Woods Hole, telling of the details of the methods he has devised "for the rearing of young lobsters up to the fourth moult, at which time, as you are well aware, the animals become pugnacious, their shells become hard, and they adopt many of the peculiarities of habit of the adult, and, moreover, they appear to be hardy and well able to look out for themselves." Professor Bumpus goes on to say— "For convenience I have termed this stage the 'Lobsterling' stage, and I am inclined to think that if we should succeed in raising even a small percentage of the fry to this lobsterling stage before liberating them, we might accomplish for the lobster fishery what the release of 'fingerlings' has accomplished for the trout fishery. Inasmuch as you are experimenting in the same line, and since one of the most important, and at the same time one of the most inviting problems of marine biology to-day is the preservation of the lobster industry, I take the liberty to tell you of our experiments during the past year, and if you should have opportunity or inclination to adopt similar methods, I should be very glad to learn of your results." The further details which are given have been sent to Mr. Andrew Scott for use in his work at Piel. During last summer the disturbance of work consequent upon the sale of the old steamer and the purchase of the new one prevented any supply of lobsters from reaching the hatchery until it was too late, but during the coming season we hope to resume work upon the hatching and rearing of this very important economic animal.

In concluding this general part of the Annual Report I desire to draw the Committee's attention once more to the pressing need of a pond or some large open-air tanks at Piel, both for the reception of spawning fish and also, later in the season, for the purpose of rearing the fry obtained by the hatching operations. The tanks would also be useful during the remainder of the year for many other purposes.*

In the special parts of this Report which follow will be found:—Mr. Scott's account of the hatching operations at Piel, with a description of the new apparatus he has devised for keeping the water in motion; Mr. Johnstone's statistics of the Mersey Shrimping Grounds; a report upon the deposits on these grounds in relation to shrimps and young fish; a note on a new parasite in the plaice; Mr. Scott's memoir on the two Copepod Fish-Parasites; and an article I have thought it well to write on the necessity for a more detailed examination of our fishing grounds, with an outline of a scheme of observational work for use on board the steamer, to which I desire to call the special attention of the Committee.

W. A. Herdman.

University College, Liverpool,
January, 1901.

* These were referred to in detail in last year's report, at p. 10.

Required Survey of our Fishing Grounds, with New Scheme of Work at Sea.

By W. A. Herdman.

In last year's Report, at p. 14, in an article on "Sea-Fisheries Conferences and the need of a 'Census' of our Seas," I pointed out 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 then proceeded to propose a scheme of investigation which I characterised as "the nearest possible approximation to a census of our seas—beginning with the territorial waters and those offshore 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 methods that we can hope to settle many important fishery questions.

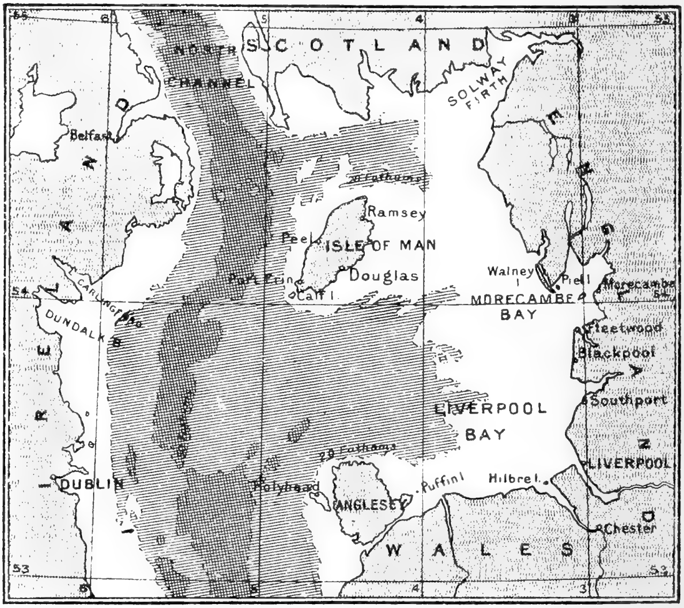
I do not think that I am under-estimating the magnitude, the difficulties and the probable imperfections of such a scheme as I propose. I am aware that all we can hope to attain is an approximation, but even a rough approximation will be of use, and if carried out on the right lines it is an approximation which will approach more and more nearly to the truth with each successive year of work.

The fishery statistics collected and published at present by the Board of Trade are, I contend, inadequate. They do not give us the information we require. The system does not seem to be designed so as to realise and tackle the problem which ought to be tackled. What we should aim at ascertaining is not what a fisherman catches, but what there is for him to catch. We must in fact get series of accurate observations which will give us fair samples of the more sedentary populations of our seas on the different grounds, such as trawling grounds, shrimping grounds, nurseries and spawning banks, at the different seasons. I have spoken of this in brief as to aim at taking an approximate "census" of the sea, but that, of course, is too ambitious a word, and indicates an exactness to which we probably could never hope to attain. Still the word serves to remind us of our approximate aim, and if we can even determine the numbers of a species on an area between wide limits, it will be of great importance.

The investigation is, of course, beset with difficulties, but they are not insuperable. One great difficulty is to determine to what extent we can safely draw conclusions from our observations. In speaking of this matter recently to a Liverpool audience I made use of a homely illustration, which may be worth repeating here as a possible help to some readers in realising the problem. I compared the investigation to the case of an aeronaut in a balloon trawling along the streets of Liverpool through a thick fog. We may suppose that a drag in the neighbourhood of University College would yield some students—male and female—and a professor; one somewhere about the docks would doubtless capture some sailors, dock labourers, and a stevedore or two, while a lucky shot opposite the Town Hall might bring up a policeman, an electric car, and a couple of Aldermen. Now, if such experiences were repeated over and over again, would the conclusions that might naturally be drawn by the intelligent aeronaut as to the relations between organisms and environment in Liverpool be correct? The observed association of students with a professor, and of both with a college, would be justifiable. It would be correct to conclude that sailors, dock labourers and stevedores frequent the docks, and that Aldermen have some connection with a Town Hall; but the fact that electric cars are also abundant in front of the Town Hall is non-essential, and any conclusion such as that Aldermen and electric cars are usually associated with the same habitat, and are in any way inter-dependent, would be erroneous.

We can imagine many other cases of this kind where appearances might at first be deceptive, and false inferences might be drawn from observed facts. On the other hand, some true conclusions would be clearly indicated; and I do not doubt that it is much the same in our investigations as to the condition and population of the sea-bottom. It is probable, moreover, that the false inferences would be corrected by the accumulation of a greater number of statistics. It might be made out from further observations that electric cars are liable to become massed in various parts of the town, and have no necessary connection with Aldermen, and that policemen are widely but sporadically distributed. The more numerous our observations, the more our statistics accumulate, the less chance is there of erroneous conclusions.

My contention, then, is that such an investigation of our seas must be made, that it is urgent and should be made now, and that the Irish Sea is favourably situated and circumstanced at present to be made a test case before undertaking the much wider and still more difficult expanse of the North Sea, complicated by international questions. The Irish Sea is of moderate and manageable dimensions (see fig. p. 144). It is all bounded by British territory and by sea fisheries authorities who might agree as to their regulations. It is a "self-contained" fish area, containing spawning banks, feeding grounds and "nurseries." It has several laboratories (Liverpool,



Plan of the Irish Sea, showing depths of water. The deepest shading is from 50 to 80 fathoms.

Dublin, Port Erin and Piel) on its borders which would form centres for investigation, and it is controlled by powerful sea-fisheries authorities, two of which at least (Lancashire and Ireland) are provided with excellent steamers which might combine in the work. All that is required, beyond a carefully considered scheme of work, is authority from the Government to the local Committees to carry out such work, and a subsidy for say five years to meet the increased expense.

The Select Committee of the House of Commons, which considered the Undersized Fish Bill last summer, clearly recognised in their report the need of some such scheme of investigations, and they recommended that a Government Department should be equipped to carry it out. I am of opinion that the matter would be better entrusted, as I have indicated above, to the local Sea-Fisheries Committees. However, there are the two methods—

1. To form a properly equipped Government Department (comparable with the Geological Survey), with laboratories and steamers and a scientific staff competent to tackle the scientific problems involved. This is the method adopted in the United States and elsewhere.
2. The other, and perhaps the more characteristically English method, is to give fuller powers to the local authorities, and to encourage them to spend money on the necessary investigations in their own districts.

Correct statistics are very important, and they could probably be taken at least as efficiently by the sea-fisheries officers, under the control and supervision of the Fisheries Superintendent in each district, as by the Board of Trade officials; but no system for the collection of statistics even if much better than that now employed can take the place of a scheme of periodic scientific observations and investigations such as I desire to see carried out all around the coast by the local Sea-Fisheries Committees.

It is, I think, agreed on all hands that what is most urgently required is facts—but facts that can only be ascertained by continuous work on a sufficiently large scale. The Select Committee on the Sea-Fisheries Bill last summer reported that the Scottish Fishery Board's "investigations have been hampered by inadequate means. They have not much money at their disposal, and the vessel which they have for the purpose of scientific investigation is undoubtedly too small."

But, incredible as it may seem, *England has no vessel at all,* large or small, devoted to the purpose of such investigations. How long will this absurd condition of affairs be allowed to continue in this rich country, with its boasted advanced position, enlightened views and keen eye to practical applications? Not only other civilised countries but even some of our own colonies are far in advance of us in the public utilisation of Marine Biological investigations.

Norway is a poor country, but, in some directions at least, an enlightened one. Here is the latest item of news in regard to her fisheries investigations:—"The Norwegian Government has built and fitted out a steam vessel for the express purpose of marine scientific research, and has placed her, as well as a trained staff of assistants, in charge of Dr. Johan Hjort as leader of the Norwegian Fishery and Marine Investigations. The vessel herself, the "Michael Sars," has been constructed in Norway on the lines of an English steam trawler—that type of boat being regarded as the most seaworthy and suitable for such an expedition—but considerably larger, being 132 feet in length, 23 feet beam, and fitted with triple-expansion engines of 300 horse-power. The fishing gear includes *inter alia,* trawls, nets, and lines of all kinds, with massive steel hawsers and powerful steam winches to work the heavy apparatus; while the numerous scientific instruments are of the very best and latest description. The expedition left Christiania in the middle of July on what may be termed its trial trip along the Norwegian coast (accompanied for part of the time by Dr. Nansen, who was desirous of testing various instruments in which he had made improvements), and has just sailed from Tromsö on a lengthy cruise to the North Atlantic and Arctic Oceans. Dr. Hjort has already added so much to the knowledge of pelagic fishes, their life, habits, and the causes affecting their migrations, that, with the means now at his disposal, a considerable amount of valuable information will probably be gained which will prove of service to the fishing industry of all nations."

What Norway can do, surely the whole western seaboard of England, from Cumberland to South Wales, now united in one Sea-Fishery District, ought to be supplied with, or be able to afford. Surely we may hope to see in the immediate future a steamer, at least of the size and equipment of a modern steam trawler, devoted solely to that combination of scientific and economic oceanographic investigations in the Irish Sea of which every conference of Fisheries Authorities, Commissions and Select Committees of recent years has had to deplore the absence.

In addition to the investigation of the bottom by dredging and trawling, the plankton in the surface and other waters of the sea would require periodic examination. This matter has been discussed fully during the past summer, both at Port Erin and Liverpool, amongst our local naturalists, some of whom have had much experience of late years in plankton work. In order to get an adequate idea of the distribution of the minute floating organisms of our seas, we should certainly require to have weekly observations (or possibly even twice a week) taken, at both surface and bottom, at certain specified stations round the coast, of which we should recognise four as being necessary in the Irish Sea, and about 15 round the whole British Coast. The Lancashire Naturalists are willing to play their part in any such general scheme, but in the meantime we are going on with the work in our own district. Mr. Isaac

Thompson at Liverpool, Mr. A. Scott at Piel, Mr. Chadwick at Port Erin, and Mr. Ascroft at Lytham, are all at work, and we have drawn up and agreed upon the following common list of pelagic organisms the occurrences and relative abundance of which in the various parts of our district will be periodically registered for each week in the year:—

Fish eggs, fish larvæ, Appendicularia, gastropod larvæ, larval lamellibranchs, larval crabs, other larval crustacea, Alteutha interrupta, Jonesiella hyænæ, Acartia sp., Temora longicornis, Isias clavipes, Centropages sp., Euterpe acutifrons, Calanus finmarchicus, Anomalocera patersoni, Pseudocalanus elongatus, Oithona spinifrons, eggs and larvæ of copepoda, Podon intermedium, Evadne nordmanni, larval Cirripedia, Echinoderm larvæ, Autolytus sp., Tomopteris onisciformis, larval Polychæta, Sagitta sp., larval Polyzoa, Ctenophora (state which), Medusæ (do.), Medusoid Gonophores (do), Noctiluca sp., Ceratium sp., Rhizosolenia sp., Chaetoceros sp., Biddulphia sp., Coscinodiscus sp., Nitzchia sp.

Mr. Ascroft is especially devoting his attention to our plankton work, and is now receiving and examining collections from various parts of the district. We hope that he will be able to contribute an account of these to our next Report.

With a view to making the best use of the time until the "census" investigations which I have recommended above are started, or until a steamer is obtained solely for scientific work in the Irish Sea, I drew up in October the following scheme of observational work which I hoped would be carried out by the new Lancashire Sea-Fisheries steamer when she started on her routine work. The scheme was submitted to the Committee, and although it has not yet been formally adopted for execution, I hope that it will now, in the light of the arguments as to the importance of such work which I have urged above, receive further consideration, and become as soon as possible an important part of the monthly work of the steamer. I reprint the scheme *verbatim* from the document privately issued in November:—

"Lancashire and Western Sea Fisheries.

"Dr. Herdman's Scheme of Investigations.

"Preston, 1900.

"*To the Lancashire and Western Sea Fisheries Committee.*

"From Professor W. A. Herdman, D.Sc., F.R.S.,

"University College, Liverpool,

"October, 1900.

"If there is one point more than another that the numerous Fisheries Congresses and Enquiries of recent years have made quite clear, it is that what we now need most for a proper understanding of the condition of the Sea Fisheries of North-Western Europe is a much more detailed knowledge than we have of the populations of all parts of our seas. Such knowledge can only be obtained by trawlings and other observations conducted regularly, frequently, and according to a definite scheme. Accurate practical work of this kind is usually called 'scientific investigation,' but it must be remembered that science is merely organised common-sense; and that any observations made accurately, and intelligently directed towards the ascertainment of facts, are scientific. The Select Committee of the House of Commons refused, last summer, to recommend the Sea Fisheries Bill because of the want of statistics based upon such 'scientific investigations.' It is thus evident that the systematic scientific investigation of our seas is of practical importance, and is very urgent, since Fisheries legislation is blocked for want of the information which such investigations alone can give.

"A scheme of scientific work has been carried out for some years on board the 'John Fell,' but the observations —although useful for many purposes—have been neither sufficiently numerous nor sufficiently regular to admit of reliable conclusions as to the abundance, movements, and life-histories of the fish being drawn. Now that a more efficient steamer has been obtained, I would urge strongly upon the Committee the importance—and even necessity —if we are to make any advance in our knowledge of how and where fishes live in the sea, of devoting a certain amount of the steamer's time to the taking of regular periodic observations at fixed points according to a definite plan.

"After full consideration of what is desirable and what is possible in our District, with a steamer which has also to carry out police and other administrative duties, I have drawn up the following, which I believe to be a workable scheme, and one which is calculated to give us the kind of information we require as a basis for the just and adequate regulation and administration of our District.

"I venture to think that if some such plan of observations had been adopted fifty or even twenty years ago, it is not too much to say that the results would be invaluable at the present day to the Naturalist and to the Fisheries Administrator alike. In face of the statistics so acquired, many of our Fisheries questions could not have arisen. There could no longer be doubt as to whether a particular Fishery, or Coast Fisheries in general, had or had not declined; as to whether the destruction of immature dabs benefitted or not the neighbouring population of young plaice; as to whether solenettes can possibly interfere with young soles of the same size; as to whether "nurseries" are already overstocked with young fish, or may with advantage be replenished as the result of artificial hatching operations.

"If public opinion has advanced, and Fisheries administration is more enlightened now than it was fifty or twenty years ago, let us see to it that the reproach of the nineteenth century is not continued on into the twentieth. I submit this Scheme to the Committee in the hope that they will authorise its immediate adoption on board the steamer, with a view to starting the new century well by having reliable and adequate monthly Fishery Statistics taken for the first time in January, 1901." "W. A. Herdman."

"Suggested Scheme of Fishery Observations.

"Regular Monthly Observations (as far as possible during the first week or ten days of each month) should be made on the following five Stations—as shown on a Chart marked by Mr. Dawson:—

STATION 1.—Blackpool Closed Ground.

STATION 2.—A similar area a little further South.

STATION 3.—Mersey Shrimping Ground, Burbo Bk.

STATION 4.—Outside N.W. Lightship to 20 fath. line.

STATION 5.—Red Wharf Bay, Anglesey.

"Stations 1 and 2 are important for comparison with one another; Station 3 gives information on shrimping and immature fish questions; Station 4 is on interesting ground, just outside the territorial waters; and Station 5 is an important trawling area in the newly amalgamated Welsh portion of the District.

"The Observations made should include:—

I. Drags with the fish trawl and shrimp trawl.

II. Plankton collections with surface and bottom tow-nets.

III. Physical Observations with thermometers, hydrometers, &c.

I.—Fish and Shrimp Trawling Observations.

" (*a*) Drags should be made under strictly uniform conditions: that is, the same 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—especially at Stations 1, 2, and 3—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*) Two or three 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 also be added.

" (*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, jelly-fish, 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. The collections should be at once preserved in formaline solution, 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. Even short hauls of half-an-hour's duration, taken twice a week, will probably suffice to give a fairly accurate idea of the movements of the Plankton in the District.

III.—Physical Observations.

"(*a*) Sea Temperatures.—Surface and bottom observations should be taken at the beginning and end of each drag. Bottom temperatures should be taken with a reversing thermometer.

"(*b*) Specific Gravity of the Sea Water.—Surface and bottom observations should be taken at the beginning and end of each drag. Bottom observations should be made on samples of the bottom water, taken with a Mill's bottle.

"(*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 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*) THE STATE OF WIND, TIDE, SEA, WEATHER, &c., should be recorded on the Form supplied.

"The above scheme applies only to the work on board the steamer. The observations carried on by the bailiffs in inshore waters should, of course, be continued, and weekly tow-nettings should be taken in each division of the District.

"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 is appended."

[N.B.—The Form on p. 155 is a compressed version of the original.]

Record of Observations made on Station No. *Date*

Positions at beginning and end of drag.

Description of net.

Time net down, beginning and end of drag.

State of tide at beginning of drag.

Weather.

Wind.

Depth during drag, beginning and end of drag.

Nature of bottom.

General remarks.

PHYSICAL OBSERVATIONS.

Transparency of water, beginning and end of drag.

Barometer, beginning of drag.

Air temperature, beginning of drag.

Surface temperature of water, beginning & end of drag.

Bottom temperature of water, do.

Specific gravity of surface water, do.

Specific gravity of bottom water, do.

General remarks.

	No. of fish selected.	Size.	Weight.	Wt. of Ovaries.	General condition.
Plaice ...					
Sole ...					
Cod ...					
Haddock..					

DESCRIPTION OF CATCH.

Name of fish.	Size in inches, 4	6	8, &c	Total No.
Sole ...				
Plaice ...				
Dab ...				
Flounder				
Lemon Sole				
Cod ...				
Whiting ...				
Haddock . .				
Skate ...				
Any other food fishes.				

Surface tow-netting—To be filled up in Laboratory.

Bottom tow-netting—To be filled up in Laboratory.

Note any unusual fishes or invertebrates.

The Fish Hatchery at Piel.

By Andrew Scott.

In last year's Report, p. 25, it is stated that white flukes were being collected and kept in the tanks at Piel in the hope of their spawning in the spring. Before the end of January 150 fish had been placed in the tanks. The ratio of the sexes was three females to two males. The fish were all collected in Barrow Channel by the local police boat in charge of Mr. Wright.

The fish thus collected, owing to unforeseen circumstances, proved to be the main source from which the eggs were obtained for incubation during the spawning season of 1900. The rough weather which prevailed in the earlier part of the year, along with the necessary arrangements for the sale of the steamer, which took place in the middle of the spawning season, prevented the steamer from doing very much to help in collecting eggs at sea or from the trawlers.

In the earlier part of the year, however, the steamer made a number of visits to the spawning grounds. On three occasions eggs were obtained, twice from the Clyde and once from fish caught by the trawlers working on the offshore grounds. The first eggs, collected from fish caught in the Clyde, March 12th-16th, were practically all lost through the rough weather encountered on the homeward journey. The second lot, also from the Clyde, arrived on March 28th in much better condition, and yielded good results. The third lot, from the offshore grounds, collected April 5th to 6th, were equally satisfactory. Altogether 2,434,800 fry were hatched and set free from the eggs collected by the steamer. A number of nearly ripe plaice were brought from the Clyde on the first visit. Some of these spawned in our tanks, yielding an additional 65,000 fry.

The first fertilised eggs from the flounders stored in our tanks were obtained on March 8th. These fish continued to supply eggs until the middle of May, and from these nearly twelve millions of fry were eventually set free. The total number of living eggs placed in the boxes was 16,000,000, and the number of fry set free 14,144,400, so that the loss during incubation was only a little over 11·5 per cent., a very low percentage. The duration of incubation was 16 to 17 days for the plaice, cod, and haddock, and 7 to 9 days for the flounder.

The success of the incubation was probably due to the healthy condition of the eggs dealt with, and also to the employment of apparatus giving a rocking motion to the hatching boxes (see below, p. 158).

The following list gives the number of fry set free, and the dates on which they were liberated. Those marked with an asterisk were hatched from eggs collected by the steamer. All were placed in some part of that wide area of our sea known as Morecambe Bay.

March	21.	1,126,000	flounder.
,,	31.	848,000	,,
April	2.	598,000	,,
,,	2.	20,000	haddock.*
,,	5.	520,000	flounder.
,,	5.	15,500	plaice.*
,,	5.	23,000	,,
,,	9.	934,400	,,
,,	9.	583,300	,, *
,,	12.	830,200	,,
,,	12.	219,800	cod.*
,,	12.	285,700	haddock.*
,,	17.	87,500	plaice.*
,,	17.	128,600	flounder.
,,	20.	1,896,000	,,

April	20.	42,000	plaice.
,,	20.	43,000	,, *
,,	23.	718,000	cod.*
,,	23.	462,000	haddock.*
,,	23.	581,000	flounder.
,,	26.	861,000	,,
May	1.	865,000	,,
,,	7.	1,447,000	,,
,,	10.	530,400	,,
,,	14.	368,000	,,
,,	22.	111,000	,,
	Total	14,144,400	

During the autumn the hatching apparatus has been thoroughly overhauled, and is now ready for use again.

A fresh stock of flounders (amounting to over 225 large healthy fish) has been collected during the last three months of 1900, so that part of the supply of eggs for the season 1901 is practically secured. With the help of the new steamer, and favourable weather, it is probable that there will be a larger number of fry set free this year than has yet been possible.

Description of an Apparatus for keeping Eggs in motion.
(See Plate A.)

To successfully incubate large numbers of floating eggs in the limited areas of the usual hatching tanks the water must be kept in constant movement. When the eggs are not disturbed they gravitate towards each other, forming a layer on the surface of the water. Consequently the result is a high mortality, chiefly due to suffocation. It becomes necessary, therefore, to employ some means to break up these masses. This is usually done by slowly raising a weighted rod placed along the rows of boxes which allows the free ends of the boxes to float up. The rod is then suddenly released, and the boxes depressed rapidly into the water, which is forced up in powerful currents through the perforated bottom of the boxes. This separates the eggs in all directions, but without injury to the developing embryos.

The mechanism employed in other establishments which use the same kind of hatching apparatus is driven by a water wheel. This wheel turns a cam which has a lever resting on its rim. One end of the lever is weighted to give the necessary pull to the wires that suspend the rods. The other end has the main wires attached, and from these branches are led over pulleys to the various weighted rods. As the cam revolves the lever is alternately raised and depressed so pulling up and then releasing the wires.

The arrangement of the hatching apparatus at Piel does not readily lend itself to the adoption of this method. Some other system had, therefore, to be planned, and after various experiments, the apparatus now adopted by us was devised. This apparatus has given complete satisfaction during the last season, and as it is less complicated than the older systems, a description and illustration may be useful to others, and will now be given.

The apparatus may be briefly described as a direct-acting balance of the beam and scale pattern. It consists in the main of a balanced beam (see Plate A, 3). One end of the beam is attached to the middle of a light framework, which carries the wires connected to the weighted rods (5). The other end bears a frame containing a "tumbling" box (4) of a similar design to those used in automatically measuring rainfall, washing photographic prints, flushing drains, &c. The box is so constructed that when empty it remains in a horizontal position, but as it fills with water the centre of gravity gradually alters until the box turns over and discharges the contents, immediately returning to the horizontal position again. The weight of the box and its frame should just be sufficient to raise the arm carrying the frame with the wires, but without the weighted rods. The quantity of water required to lift the rods and weights is found by weighing one rod with its weight, and then multiplying that by the number of weighted rods employed. The box should be made to contain rather more than the exact quantity of water required. In the Piel Hatchery the waste water from the apparatus and other tanks is used for filling the box. When the box is empty the rods are down and all the hatching boxes are depressed. The box (4) gradually sinks to the floor as the water pours in, pulling up the weighted rods (5). By the time the rods are raised high enough (6 inches) the box has lost its stability, and it falls over, discharging its contents at once. The rods at the same instant return rapidly to rest, depressing the hatching boxes. The rate of movement is easily controlled by regulating the flow of water, and also by retarding or hastening the period of instability of the tumbling box. This latter can be done by adding weights to the side of the box at B, or by placing pieces of wood on the frame under the box at D.

The apparatus when fitted up can be attached to a beam in the roof of the room, and the whole should be so placed that the framework carrying the wires attached to the rods is vertically above the point of attachment.

Explanation of Plate A.

The drawing represents the front view of the apparatus.

1. Longitudinal beam resting on the cross beams supporting the roof.

2. Support for apparatus.
3. Balanced beam.
4. Tumbling box. At C a brass rod is rigidly fixed working freely in lignum vitæ bearings fastened to the frame. AB = $35\frac{1}{2}$ inches, AC = $27\frac{1}{2}$ inches, CD = $9\frac{1}{2}$ inches, BD = 11 inches. Width = 12 inches.
5. Wires to rods.
6. End view of hatching tanks, containing little boxes for eggs.
7. Waste pipes leading into main pipe, taking water to tumbling box.

a End view of top and bottom of main suspender.

b End view of suspenders of framework for wires and tumbling box. The suspender to the tumbling box works through a guide (*g*).

c Side view of tumbling box in its frame.

NOTE ON THE SPAWNING OF THE MUSSEL (MYTILUS EDULIS),

By A. SCOTT.

The determination of the spawning period of the mussel on the Lancashire coast has occupied our attention for some time. Hitherto we have mainly examined the condition of the reproductive organs, both *in situ* in the living animal, and by thin sections of prepared material during periods of twelve months. Tow-nettings from the vicinity of the beds have also been examined for the larvæ. These investigations enabled us, approximately, to state when the eggs were shed. It is obvious, however, that all the information regarding the actual spawning, the fertilisation of the eggs, and the period that elapses before the resulting embryos become free-swimming larvæ can only be ascertained by carefully observing the living animal. It is not possible to do this under natural conditions on the beds, and it becomes necessary to fall back upon other methods which may not give altogether conclusive results from a critically scientific point of view. To remove animals from their natural surroundings and place them in confinement in a limited area of water is undoubtedly detrimental to life processes at first. After some time the effects produced by the change may however be diminished, and the animals become acclimatised and live probably very much as they would have done had they been left in their original state. We are thus enabled to carry on observations which would be quite impossible under natural conditions.

Large samples, about ½ cwt., of mussels were collected from the Roosebeck outer scar and from a scar in Barrow Channel which only ebbs dry at low water of spring tides. These were placed in the tanks in September, 1899, and kept under observation for twelve months. A constant current of sea water was maintained, and from time to time, usually twice a week, small quantities of mud, known to contain diatoms, &c., were added to supply the animals with food. The animals were examined microscopically at intervals, and the reproductive organs compared with samples taken direct from the beds. The rate of development was found to be practically the same in the mussels in the tanks and in those on the beds.

On May 6th the mussels from both beds commenced to discharge eggs. These were isolated and examined under the microscope. No development took place. No ripe males were found at this period, and it may be concluded that these eggs were not fertilised. The mussels continued to discharge eggs which underwent no change until June 14th. On June 13th the first obvious discharge of spermatozoa occurred. This was from the mussels from Barrow Channel, and so abundant was the supply that the water in the tanks was rendered quite turbid, as if milk had been poured in. A drop examined under the microscope was found to be teeming with spermatozoa in active movement. Two days afterwards the Roosebeck mussels discharged spermatozoa. From that date onwards, although no further discharge of spermatozoa was observed, the eggs were always fertilised. With a very few exceptions the eggs were discharged during the night. Many of the mussels were actually observed in the act of shedding their eggs.

The embryos flow from the female in a slow distinct stream. When not disturbed by currents they settle down on the mud close to the parent as an obvious pink mass. They remain in this position undergoing the early stages of development, which last from eight to twelve hours. They then rise to the surface as free swimming larvæ, and are dispersed by the currents. The duration of the free swimming stage was not determined, but the larvæ remained free swimmers for at least four days. The minute size of the larvæ (they are only from $\frac{1}{363}$ to $\frac{1}{250}$ of an inch in diameter) prevents accurate observations being made for one individual. They can only be kept in jars where no circulation is going on, consequently the surroundings soon become unfavourable to life. Attempts to strain them through fine sieves, and so allow the foul water to escape, were not a success, as the larvæ passed through our finest sieves.

Fertilisation of the eggs has generally been thought to take place in the water after they were discharged from the parent. That has not been our experience at Piel. After the obvious discharge of sperms all the eggs subsequently extruded were found to be fertilised, even though no further discharge of spermatozoa could be detected. In several instances the eggs were isolated as they were leaving the parent and put into water direct from the sea that had been carefully filtered through fine filter paper. These eggs always developed into free swimming larvæ. Fertilisation therefore probably took place in the branchial chamber of the parent.* It was also observed that practically the whole of the reproductive elements were discharged at one emission extending from one to three hours. The same mussel did not again set free any more reproductive elements. When such a spent mussel was opened up and examined the whole reproductive organ was found to have collapsed.

The mussels on the beds, by the time those in the tanks had ceased to emit reproductive elements and had become quite thin, also took on the same appearance. From the observations carried on at Piel the conclusion has been arrived at that the spawning period of the mussels in the northern part of our district may be set down as having lasted this year (1900) from the beginning of May to the middle of July.

Report on the Shrimp Trawling Statistics Collected by Mr. G. Eccles on the Mersey Shrimping Ground during the period 1893—1899.

By Jas. Johnstone, B.Sc., and J. T. Jenkins, D.Sc.

In 1893 the Committee began a series of observations, on the lines indicated in a scheme drawn up by Professor

* Professor M Intosh some years ago investigated various points in the reproduction of the mussel. Amongst other things, he determined that the sperms were capable of living for twenty-four hours after being removed from the parent. This has been confirmed by the work at Piel, but the intervals between the obvious shedding of sperms and eggs in the tanks were much longer than twenty-four hours, and during these periods the sperms, even if alive, would be carried away in the waste water.

Herdman,* on the occurrence and distribution of the commoner food fishes on the principal inshore and offshore grounds of the Lancashire District. From time to time selections from the results so obtained have been published either in the Superintendent's Reports or in those of this Laboratory. In the autumn of 1899 it was thought advisable to make a study of all the data obtained, and as a result all the forms (over 1,000) containing the records of the observations have now been abstracted.

These observations were made by the Captain and crew of the "John Fell" and by the bailiffs in charge of the sub-districts, and are as complete as the police work and other administrative duties of the officers permitted. They include experimental hauls with fish-trawl nets of various sizes and made under various conditions, hauls with shrimp trawls and shank nets, and observations on the sizes, spawning, feeding, &c., of the common food fishes. On account of the limited staff employed, the extent of the district to be worked over and the pressure of the police work, these statistics are necessarily very imperfect. It would be premature to publish many of the data obtained, especially those of the fish-trawl, at present, and we therefore confine ourselves to what seems most complete and reliable, viz., the series of experimental hauls with shrimp-trawl nets made by Mr. G. Eccles, head bailiff for the Southern District, on the Mersey Shrimping Grounds.

It would not serve any useful purpose to publish the results of these hauls as recorded by Mr. Eccles in full, so we have prepared an abstract of all the data collected and present it in the form of Tables I. to VI. Altogether 248 hauls with a shrimp trawl were made during the period 1893-1899. By far the greatest number of these

* Lancashire Sea Fisheries Laboratory Report for 1892, pp. 41-45.

were made from the New Brighton sailing boat. A few were made by the "John Fell," and are included amongst the others. The conditions under which the hauls were made were not strictly uniform. As a very general rule a shrimp trawl of 21 feet beam and 33 feet length of net, with a mesh measuring half an inch from knot to knot, was employed. Very occasionally a slightly longer beam (24 feet) has been used. The greater number of the drags made were two miles in length and one hour in duration, and these conditions were adhered to as closely as circumstances permitted. Occasionally, however, the length and duration of the drags were greater, more often less, than the values stated, and from this cause individual hauls are, strictly speaking, not comparable with each other. In the treatment of the data it has, therefore, been thought advisable to make the average hauls per month the values compared, and as the averages of a number of hauls have generally been used in whatever comparisons we make, to that extent the error due to fishing under slightly inconstant conditions has, we consider, been eliminated.

The recorded results of these hauls include (1) the total numbers of edible fish caught, (2) the numbers of quarts* of shrimps taken, (3) the numbers of the various species of food fishes with (generally) their average sizes, (4) state of weather, sea, wind, &c., (5) physical observations. The commoner fishes taken are:—The sole (*Solea vulgaris*), the plaice (*Pleuronectes platessa*), the dab (*Pleuronectes limanda*), the haddock (*Gadus æglefinus*), the whiting

* We employ the quart of shrimps (the economic unit) as the measure of the catch. A quart contains a variable number of shrimps, 200 to 400, the variation being due to the varying sizes of the animals. The market value varies from 6d. to 8d., that is the price paid by the consumer; the fisherman himself receives only about 3d. per quart on the average if he sells his catch to the fishmongers. But a considerable proportion of the shrimps caught (about one-third) are retailed by the fishermen themselves.

(*Gadus merlangus*), the cod (*Gadus morrhua*), and the herring (*Clupea harengus*). Less commonly the lemon sole (*Pleuronectes microcephalus*), the brill (*Rhombus lævis*), and the gurnard (*Trigla gurnardus*) are taken. Various inedible fishes are frequently caught, the commoner of which are *Solea lutea, Trachinus, Cottus, Centronotus, Ammodytes,* and with every haul a great number of invertebrates are taken. Often the crabs (*Portunus*) brought up form half the bulk of the catch. Starfishes (*Asterias*) are nearly always caught. In the warmer months large medusæ are abundant.

We quote a few individual hauls in detail as samples.

I.—August 28th, 1893. Near Deposit Buoy (see chart on p. 46), in 5 fathoms of water, bottom of sand and mud. Length of drag = 2 miles, duration =70 minutes. Shrimp trawl of 21 feet beam.

Sole ...	43,	length =	4½ inches mostly, but 16 were over 4oz. in weight.	
Plaice ...	1620,	,,	6 inches.	
Dab ...	604,	,,	6 ,,	
Whiting	757,	,,	6 ,,	
Cod ...	88,	,,	5 ,,	
Gurnard	30,	,,	4 ,,	
Ray ...	2,	,,	7 ,,	broad across pectoral fins.

Total food fishes 3144. Shrimps, 27 quarts.

II.—September 27th, 1893, near Deposit Buoy, in 5 fathoms of water; bottom of sand. Length of drag = 2 miles, duration = 90 minutes. Shrimp trawl of 21 feet beam. Twenty boats were fishing immediately around.

Sole ...	12,	length =	4½ inches.
Plaice ...	10407,	,,	4½ ,,

Dab ...	375,	length = 4	inches.
Whiting	169,	,, 5	,,
Cod ...	69,	,, 5	,,

Total food fishes 11032. Shrimps, 32 quarts.

The soles and plaice taken in this haul are described as "deadly," dabs, whiting and cod as "lively."

III.—August 30th, 1899, near Deposit Buoy, in 6 fathoms of water; bottom of mud and sand. Length of drag = 2 miles, duration = one hour. 21 feet shrimp trawl.

Sole ...	257,	11 were over 8 inches long, $\frac{1}{3}$ of the catch were over 2 and under 8 inches, the remainder were 2 inches long.
Plaice...	265,	6 were over 8 inches long, the remainder were 2 to 4 inches in length.
Dab ...	896,	2 were over 8 inches long, $\frac{1}{4}$ of the catch were about 2 inches, the remainder $1\frac{1}{2}$ inches long.
Ray ...	18,	7 inches broad.
Whiting	285,	5 inches.

Total food fishes 1721. Shrimps, 20 quarts.

IV.—March 15th, 1895, in Crosby Channel (see chart), in 4 fathoms of water. Bottom of sand. Length of drag = 1 mile, duration = 30 minutes. Shrimp trawl 24 feet beam.

Flounders ...	2,	length = 4	inches.
Cod ...	10,	,, 7	,,

Total food fishes 12. No shrimps were caught.

II. is one of the largest hauls made on the ground. IV. is one of the smallest. It will be seen later, however, that the hauls made on the ground dealt with in IV. differ considerably from those made near the Deposit Buoy.

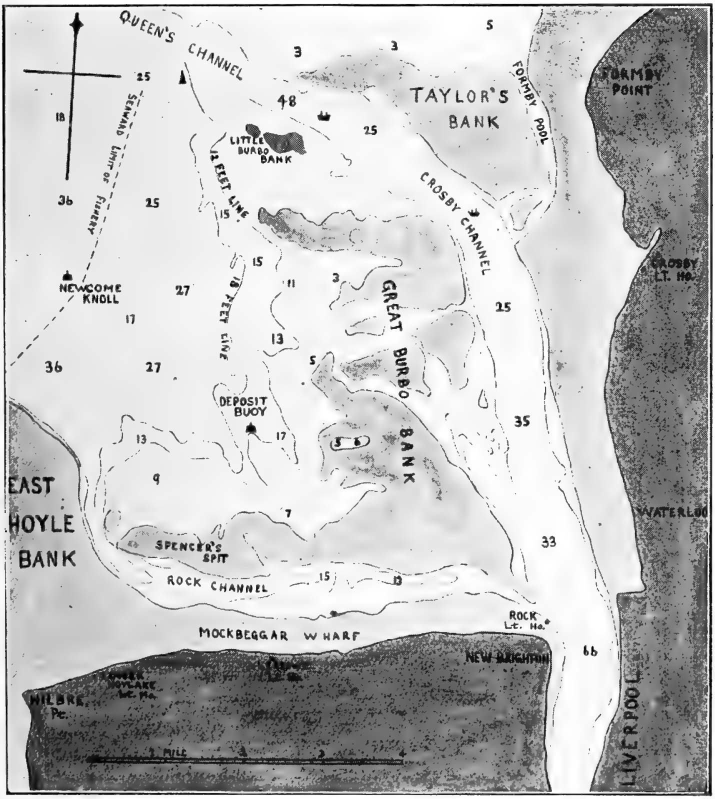
The actual data considered here are given on Tables I. and II. Of the various species of edible fish enumerated above only 4 are dealt with—the sole, plaice, dab, and whiting. Consequently the totals under the heading "Total numbers of fish" are not the sums of the numbers representing the catches of the four fishes mentioned. Those sums are less than the totals by the numbers of fish of various kinds which are not tabulated. For each of the years 1893-99 the tables give (1) the number of hauls made during each month, (2) the total number of fish caught in all the hauls and the average number of fish caught per haul, (3) the total number of quarts of shrimps caught in all the hauls and the average catch per haul, (4) the total number of each of the four kinds of fishes caught in all the hauls and the average numbers caught per haul.

Table I. deals with the observations made on a portion only of the whole Mersey shrimping ground. Most of the hauls have been made within two miles of the Deposit Buoy, that is on the shallow water immediately behind Burbo Bank. A few were made in a small portion of the Rock Channel (see Chart, p. 171).

Table II. gives the hauls made in the deeper water of the Channels—part of Rock Channel, Horse Channel, Queen's and Crosby Channels. The division of the whole ground into these two sub-divisions is not quite natural since all the Rock Channel ought, strictly speaking, to have been dealt with in Table II. But it was found convenient for various reasons to include the eastern portion of Rock Channel in Table I.

It will be seen that there is no complete series of observations, including at least one haul in each month of the year in either Table I. or II. On this account and also with the object of eliminating as far as possible accidental conditions and variations, all the hauls taken during the Januarys in each of the years 1893-99 have been collected, and from these the total fish and shrimps caught and the averages per haul have been calculated. The same has been done for the other months, and the results are tabulated in Tables III. and IV. III. deals with the portion of the ground considered in Table I., and IV. with the portion considered in Table II. In Table VI. all the fish caught in the third quarters (July, August, September) of each of the years 1893-9 are collected, the numbers of hauls taken in each of those quarterly periods are given, and the average catches are calculated. In Table V. an attempt is made to compare the varying destruction of young fishes at different times and on the different grounds.

We give on next page a map of the Mersey Shrimping Ground which has been reduced from the Liverpool Dock Board's Chart of the area. It represents the extent of the sandbanks at low water of a spring tide ten feet below the level of the Old Dock Sill Datum at Liverpool. Almost the whole of the area shown is regularly fished over. More exactly, a line drawn from the N.W. extremity of East Hoyle Bank to Newcome Knoll Buoy, and from Newcome Knoll Buoy to the first red conical buoy in Queen's Channel, defines the seaward limit of the Burbo Bank area. Shrimping is carried on over almost all this ground, the extent of which is roughly 16 to 18 square miles. Queen's Channel, Formby Channel, Crosby Channel, Horse Channel, and the western portion of Rock Channel are also regularly fished. Shrimping is also carried on in the gutters through the banks, and when there is sufficient water on the margins of the banks themselves. A portion of this area, about 4 square miles in extent, lying between Newcome Knoll and Deposit



MERSEY SHRIMPING GROUNDS.

Buoys and to the north of these, has a bottom of fine mud, which to some extent hinders the working of shank nets. Over almost all the rest of the area the bottom consists of fine sand. Shrimp fishing, however, is not confined to this area. A considerable area to the north of Queen's

Channel and a portion of the Mersey estuary lying above the Liverpool Landing Stage are also fished on.

Now with regard to the relative quantities of shrimps and immature fishes caught in the shrimp trawl, considerable differences exist on different parts of the whole area referred to above. We have, therefore, separated the hauls taken on the portion lying seaward from Burbo Bank and south of Queen's Channel from the portion including Queen's, Formby, Crosby and Horse Channels, and the eastern part of Rock Channel. For convenience the former portion will be referred to hereafter as Area A and the latter as Area B. The hauls taken on Area A are abstracted in Table I., those taken on Area B on Table II.

In Plate B we have represented graphically the results of Tables III. and IV. The method adopted has been to take each fish separately, and to superpose the curves representing its distribution on the two sub-divisions of the shrimping ground referred to above. Curves I., II., III., IV., and V. represent the variation from month to month in the numbers of immature whiting, plaice, dabs, soles and shrimps taken per average haul. In all these curves the number plotted along the vertical axes represent these average hauls; months are represented on the horizontal axes. The vertical scale of I., II., and III. is the same; the corresponding scale of IV. is one-tenth, and V. one-twentieth that of I. This change of scale has been necessary on account of the small values dealt with in IV. and V. In all the curves the thick line represents the average hauls on Area A, the thin line the average hauls on Area B. It ought to be remembered that the fishes dealt with in these tables and curves are nearly all immature. The hauls quoted on pp. 167-168 represent fairly their average sizes.

In the case of the whiting (I.), the maximum catch (1,180) has been taken in August. This is the case on both areas, and it is the case also for Area A in 1893, 1894, 1895, and 1899. In 1896 the maximum catch was taken in July, in 1897 and 1898 in September. The series for individual years are not so complete for Area B, and it is to be noted that in 1895 the catches increase during the latter half of the year to a maximum in November. The catches of whiting during the third quarter of the year were greater in 1895 than in any other year of the period under consideration. In both areas very low catches were made in June, and after this month the curve rapidly rises towards the maximum in August. A secondary maximum (on both areas) occurs during April. It is remarkable that the form of the curve is the same for both areas, the maxima and minima occurring at the same time. The curve also shows that throughout the year greater catches were always taken on Area A, and that between June and November the catches there were very much greater than on Area B.

In the case of plaice (II.) the maximum catch was made on Area A in September. This is also true for the three years, 1893, 4, and 5, having the most complete series of observations. The minimum occurs at the end of the year. It is generally the case in the individual years that the lowest catches were made at the beginning or end of the year. As in the case of whiting, a secondary maximum occurs during the spring.

The form of the curves for plaice differs completely for the two areas. In B there are three maxima, January, July and November, and two minima, May and August. Generally it would appear that plaice are more abundant in the Channels during the winter months, that during the late winter and spring their number decreases, and increases again toward midsummer. After midsummer they become less abundant, but during the autumn and early winter they increase again. That is to say, that except for the increase towards midsummer, which is characteristic for both grounds, and is largely due to the appearance of fish of that same year's spawning, their distribution on the two areas is to some extent complementary. The general conclusion is confirmed by the study of the figures for the separate years (as far as these go). This curious behaviour of the same fish on two adjacent areas is perhaps to be explained by supposing that migration from the one area to the other takes place during the spring and autumn. What the causes of such migration may be we are not in a position to say. The migrating fish are largely those of that same year's spawning.

It might be expected that the distribution of dabs would follow closely that of plaice. It will be seen that the curve of distribution (III.) on Area A is very similar to that for plaice. The minimum for both fishes occurs at the beginning or end of the year, but the maximum catch was taken earlier in the year in the case of the dab. In the three years, 1893, 4, and 5, for which the data are most complete, the maximum catches of dabs were made earlier than those of plaice. As in the case of whiting the curve shows two maxima which have the same positions.

The distribution of dabs on Area B is not exactly similar to that of plaice, but seems to be rather irregular. It is, however, the case that large catches were made there at the beginning and end of the year. The catches made about the middle of the year are, however, somewhat irregular.

Soles (IV.) have much the same distribution on Area A as the other fishes dealt with. The maximum catch was made in August. The secondary maximum occurs in March, a month earlier than that of dabs and whiting. The minimum catch was made at the end of the year. Three hauls were made on this ground during December, in none of which were soles caught. The distribution on Area B is more irregular, and no general statement can be made with regard to it.

Shrimps (V.) have been caught at any time during the year on both areas, except in one exceptional haul (quoted on p. 168). It is to be noted that their distribution differs somewhat from that of the food fishes; the minimum catches were made (on both areas) in February. From then the average catch rises with small variations to the maximum in October. During August, September and October the catches do not vary much, rising very slowly. After October they fall very rapidly.

A study of the curves representing the monthly variation of shrimps on the two areas shows this remarkable condition: from December till the following August shrimps are always more abundant on Area A than on Area B; conversely from August to November they are more abundant on Area B than on Area A. That is to say, during the four months, August to November, shrimps are more abundant in the channels than on the banks. We think it necessary, however, to state that this may be due to the fact that most of the fishing is carried on during these four months on Area A.

Since all shrimp fishing, whether on Area A or B, is necessarily attended by the capture of a variable number of immature fish, we have thought it useful, in view of the practical importance of this fact, to study the variation in the relative quantities of shrimps and fish caught in the shrimp trawl. If the number of fish caught in any one haul be divided by the numbers of quarts of shrimps taken at the same time, a measure is obtained of the amount of destruction of young fishes caused by shrimp trawling. Taking the total monthly catches of shrimps and fish during the year, as shown in Tables III. and IV., as a basis, we have constructed Table V. That table shows for each month in the year, and for both areas, how many soles, plaice and whiting were caught for every quart of shrimps. And if it be possible to determine by any means the total number of quarts of shrimps landed from the Mersey Shrimping Grounds in each month during the year, the numbers on this table will serve as factors which will enable the amount of destruction of immature food fishes to be calculated.

The numbers of plaice caught per quart of shrimps on Area B during February and March seem excessive. This is due first to the relatively large numbers of plaice found on that ground during the early months of the year; second, to the very small catches of shrimps made there during those months.

The tables show that the numbers of soles, plaice and whiting caught per quart of shrimps on Area A is always much greater during the third quarter of the year than on Area B during the same period. More exactly, more whiting are caught on Area A from June to December, and more plaice and soles from August to October, than on Area B during those same months. More whiting were caught on Area B than on A during February, and more soles during March, May, June, July, November and December.

We have used the term destruction as synonymous with capture of young fish, but perhaps we are not strictly justified in doing so. All the fish brought up in a shrimp trawl do not necessarily die. It will be seen by reference to the hauls quoted on pp. 42-3 that a few large fish are generally taken. These are always alive when brought up from a drag of moderate duration, and if immediately thrown back into the sea will most probably survive. We refer to plaice, soles and dabs over 8 inches in length. Flat fish from 3 to 8 inches are not so hardy, but many of these are alive when the "net is fished," and probably recover when put back into the sea. The vitality experiments made by Mr. Dawson* and others in our district have shown that quite a large proportion of such fish recover when taken from the contents of the net and immediately put into a tub containing running sea water. But the flat fish under 3 inches long are in a worse case, and the greater number of these are probably really destroyed. They are small, and in the process of "sorting the catch," all the larger animals (large fish, crabs, star-fish) are thrown overboard first, so that small flat fishes have to lie on the deck for a longer period than the others. Small round fish, whiting, haddock and cod of less than 5 inches long are almost always dead when the contents of the net are emptied on the deck. The larger round fishes may be alive, but they seem to be less hardy than the flat fishes.

Of course the mortality among the fishes caught in the shrimp trawl must depend to a very great extent on the care of the fishermen in sorting the catch, on the facility with which the net can be hauled, on the duration of the drag, and on the temperature; in warm weather the water adhering to the gills is more easily evaporated and contains less dissolved air. It is to the interest of the fishermen to sort the catch quickly, and get the

* Lancashire Sea Fisheries Laboratory Reports for 1893, (p. 23) and 1894, (p. 30).

shrimps put aside, and we believe that they really wish to preserve the life of as many of the immature fish caught (which are not marketable, and are of no use to them) as possible. And we have seen that the contents of the net can be very rapidly sorted out. But in a large catch the process is somewhat tedious, and as the deck space in a shrimping boat is very limited, part of the catch may be put into fish baskets *unsorted*, while the remainder is being dealt with. In these circumstances the immature fish in the reserved portion have little chance of life.

It is clear that with long drags, with large catches, and in warm weather the mortality among the immature fish taken in the trawl is much greater. Considering all things, there is not much doubt that of the immature fish taken in the course of shrimp trawling, as at present carried on, a large proportion must necessarily be destroyed.

We have made an attempt to determine the distribution from year to year of the four fishes considered above. The average hauls for each fish for the third quarters of each of the years 1893-9 have been calculated, and these are the values compared. The third quarters (July, August, September) are selected since those are the periods during which the greater number of hauls were made, and because they contain the maximum catches for all the years and fishes considered. The values dealt with, therefore, are those representing most probably the condition of the fishery in each year. The results are tabulated in Table VI., and they are represented graphically in the corresponding set of curves (VI.) on Plate C.

During this period the average catches of plaice have decreased from the maximum catch (2,045) in 1893 to the minimum (176) in 1899. The decrease from 1893 to 1894 was very great. From 1895 to 1897 the catches were nearly constant, dropping again in 1898. The maximum catch of dabs was made in 1894; from 1894 to 1897 the catches of dabs steadily declined, recovering again in 1898. The maximum catch of whiting was made in 1895, and the catches then decreased till 1897, when they again began to increase. It is singular that the maximum catches of these three fishes, plaice, dabs, and whiting, are observed in three consecutive years.

The catches of soles, on the contrary, show a nearly regular increase during those seven years. The minimum catch was made in 1894, the maximum in 1898. The decrease from 1898 to 1899 is very slight. We have evidence that a similar, though greater, increase in soles has taken place on the Blackpool closed ground.

No deduction as to the effect of fishing on the distribution of these fishes during the period considered can, of course, be made. The period is too short and the variations observed are too great. There can be little doubt but that the fluctuations are due in the main to the operation of natural causes.

We must insist on the inadequacy of these statistics to a thorough understanding of the causes influencing the distribution, on different areas and at different times, of the fish population of the Mersey shrimping grounds. So far as they go they are valuable, and they do give some information regarding the seasonal variation and the relation to each other of the various forms considered. But they suggest many more problems than they aid us in answering. The increase in the catches of soles on the Blackpool and Mersey grounds is an instance. This happening on two grounds, one preserved against, the other open to, shrimp trawling, is remarkable. A satisfactory answer might have been given by a much more complete series of observations than we possess, which might have enabled us, from a consideration of the relative increments in the catches from year to year, to have connected the increase on the Blackpool ground with its closure against the destruction of immature soles by shrimp trawling. But comparatively few hauls have been made on the Blackpool ground, and the opportunity has been lost.

No regular observations regarding the distribution of the plankton or of the bottom invertebrate fauna of the Mersey ground have been made, and we have therefore no material for a possible explanation of the fluctuation in the fish fauna outlined above. It is particularly unfortunate that regular and exact physical determinations of temperature, specific gravity, salinity, &c., were not made during the last eight years. These must be essential portions of any future investigation of this area.* The nature of the sea bottom is very peculiar, and a complete investigation of this is to be desired.

We believe that observations on this ground, with a view to the regulation of the fishing, will be unsatisfactory unless accompanied by enquiries into the relations of its fish population with the spawning fish on the offshore grounds on the one hand, and with the larger immature fish population of the offshore grounds on the other. Such investigation and enquiries into the stability of the immature fish population of the shrimping ground are very relevant.

* See scheme given in this Report, p. 149.

Report on the Deposits from the Liverpool "Hoppers" in Relation to Shrimps and Young Fish.

By W. A. Herdman.

Early in the year the General Purposes Committee asked for a report on the effect produced upon the movements of shrimps and young fishes by the materials carried out to sea from Liverpool in the hopper barges and deposited near the Burbo Bank. It had, I believe, been suggested (1) that the shrimps were attracted to this particular ground—where young fishes are also found in great abundance—to feed upon the refuse in the deposits; and (2) that if the attractive material were deposited on some other neighbouring ground not frequented by small fish the shrimps would follow, thus leading to such a separation of shrimps from young fish on the bottom as would admit of shrimping being carried on freely without causing any destruction of young fish. It would certainly be very convenient if it were so, but a careful examination of the facts shows that there is no real foundation for the ingenious suggestion.

Mr. Dawson, after discussing the matter with me, caused the necessary samples and specimens to be obtained from chosen localities in the area in question, and these were sent to the laboratory where Mr. Johnstone and I carefully examined them, and drew up the following report for the Committee:—

"Report by Dr. Herdman on Deposits, Shrimps, and Young Fish.

"A number of samples have been obtained during the last two weeks by Mr. G. Eccles, and were brought by him to the Laboratory for examination.

These represent:—

1°. Samples of the sea bottom at and about the "Deposit buoy." (See map on page 171).

2°. Samples of the sea bottom near the Rock Channel (No. 7 buoy).

3°. Samples of the deposit found in gutters on the edge of the Burbo Bank at low tide.

4°. Material taken from a "Hopper" in the Manchester Ship Canal.

5°. Samples of shrimps caught near the Deposit buoy.

6°. Samples of young flat fish caught near the Deposit buoy.

"These have all been carefully examined in the Sea-Fisheries Laboratory, and microscope preparations of the various substances have been made and compared.

The examination has shown:—

1°. That there is comparatively little fine mud or dirty material at the Deposit buoy. The bottom appears to consist largely of coarse crystalline sand.

2°. At No. 7 buoy the deposit is dirtier, and has more mud and amorphous decomposing material.

3°. In the gutters at low tide the deposit is also dirtier than at the Deposit buoy, and more like the refuse from the Hoppers.

4°. The material from the Hopper was very dark coloured, and had much more yellow and black amorphous decomposing stuff than is found on the sea bottom at or near the Deposit buoy.

5°. The shrimps caught about the Deposit buoy contained in the stomachs—sand, vegetable tissue, animal debris, legs, &c., of small Crustaceans, Foraminifera, Annelid setæ, along with a certain amount of sand.

6°. The stomachs and intestines of the young fish (mainly dabs) brought to the Laboratory from near the Deposit buoy were full of sand, with fragments of shells and remains of animals.

"CONCLUSIONS.—So far as these samples show, there is no reason to think that either the shrimps or the young fish feed upon the stuff deposited by the Hoppers. They did not show any traces of it in their stomachs, nor are they specially abundant where the bottom shows the greatest amount of dirt and decomposable material."

"University College, "W. A. HERDMAN."

"*March 15th, 1900.*"

Mr. Dawson and I therefore agree that it is a mistake to suppose (1) that the Liverpool refuse is especially abundant at the bottom in the neighbourhood of the so-called "deposit" buoy, which is on the Burbo Bank Shrimping Ground, and (2) that shrimps feed specially upon such refuse. Consequently the idea that the shrimps are attracted to the ground they frequent by the Liverpool deposits may be relinquished, and it is very improbable that changing the place of deposition would have any favourable effect upon the present distribution of shrimps and young fish.

As a matter of fact, as Mr. Dawson has pointed out in one of his quarterly reports, the steam hopper barges conveying the refuse generally go much further out to sea than the area in question before discharging; and, with the exception of sand, no material of any kind has apparently been deposited in the neighbourhood of the deposit buoy and from there to the Burbo Bank for some time.

It is probable that the conditions in these shallow sandy channels which suit the shrimps are also the most suitable conditions for young fish—especially flat fish—in certain stages of growth, and consequently it is futile to hope that any artificial operations will lead to the separation of the two kinds of animals.

Note on a Sporozoon Parasite of the Plaice. (Pleuronectes platessa).

By James Johnstone.

(With Plate D.)

Two specimens of plaice have come to the Fisheries Laboratory during the year which showed a peculiar modification of the intestinal wall. One specimen was sent by Mr. G. Eccles, Chief Fishery Officer at New Brighton. It was caught near the Mersey Bar at the beginning of October. The other was sent to me by Mr. A. Scott. It had been caught by Mr. Wright, Fishery Officer, in Barrow Channel, on October 1st, 1900.

The first specimen was a female about 8 inches long. It had been opened, and the head cut partly off. Mr. Eccles was struck by the granular appearance of the viscera, suggesting the presence of a large quantity of spawn. As however the fish was much too small to contain ripe ovaries, he thought it worth sending to the Laboratory. It was fresh when it came to hand, and the fish looked in good enough condition. The ovaries were about one inch in length but perfectly normal for a fish of this size. The intestine, liver, kidney, &c., had their usual relations.

But the greater portion of the intestine, from the pylorus to about $1\frac{1}{2}$ inches from the anus was thickened, and had the appearance of a ripe ovary. That is, the surface was studded with little round white opaque bodies lying close together, and shining through the peritoneum. The fresh intestine was precisely similar to that of the second specimen, which is represented in Plate D, fig. 1. On cutting open a portion of the gut it was seen to have a much reduced lumen. The wall was 3 or 4 mm. thick. Its internal surface was thrown into close set and deep longitudinal folds pursuing a zigzag course. All the surface of these showed the same round white bodies projecting from their surfaces.

The stomach was normal in form and relations except that its walls seemed thinner than usual. No food contents were present. In the modified portion of the intestine there were traces of decomposed food matter. A few fragments of Lamellibranch shells were found, and were identified as young *Donax vittatus*.

The second specimen, sent by Mr. Scott, was the intestine of a female plaice 11 inches long. It had been preserved in corrosive-acetic fixative before reaching here. From Mr. Scott's description the fish seems to have been quite normal in other respects. The ovaries were of normal size and relationships.

Almost the entire post-pyloric portion of the intestine in this specimen was modified in precisely the same way as in the other case described above. Fig. 1 represents a portion of the intestine of this fish. The maximum diameter was about 1 inch. This thickest portion lay immediately behind the stomach. The pyloric caeca could be recognised, but were greatly flattened out. Near the anus the inclusions in the wall became fewer, and a small portion was free from them. No traces of food matter could be recognised in the lumen.

Pieces of both intestines were hardened in alcohol, embedded in paraffin, and sections were made. Fig. 2 represents a small portion of the wall of the first specimen cut in transverse section. No mucous membrane is recognisable, and the whole wall is filled up with roundish bodies, each of which appears on examination with a moderately low power to be filled up with a homogeneous material. These bodies are closely packed together, and between them lie a few connective tissue fibres. Some masses of disintegrated tissue lay between the folds which may possibly have represented the disintegrated mucosa. Fig. 3 represents a small portion of the same section under a much higher magnification. Outside of all may be seen a layer of peritoneum (*Per.*) and internal to this is a thin longitudinal layer of plain muscle fibre (*Ml.*). Within this layer of longitudinal muscle fibres is a layer of circular fibres (*M.c.*), also unstriated and about three times the thickness of the former layer. Within this, again is a layer of loose areolar tissue (*S. muc.*) from which fibres pass through the thickness of the wall of the intestine between the spherical bodies.

The arrangement of the muscle layer is therefore normal, and the foreign structures lie in the sub-mucosa. Of the mucosa itself there is no definite trace. A delicate sheet of connective tissue covers the free surface of the folds. This is easily torn, and the little spherical bodies can be readily dissociated. They are perfectly spherical in the fresh state, and have an average diameter of about 0·6 mm. The structure of a portion of one of these cysts is shown in Fig. 3. There is a capsule (*C.c.*), consisting of an outer cuticular layer and an inner irregular layer, which is fibrous in appearance, and apparently contains no nuclei. Within this capsule the cyst is filled up by a vast number of minute spore-like bodies. These are oval in shape. They have a maximum diameter of about 5 μ. They do not stain, and present no obvious internal structure.

It is obvious from the above description that we have to deal here with a Protozoon parasite, most probably a Sporozoon form. Possibly it is one of the Gregarinida, but at present I am unable to determine the genus.

Explanation of Plate D.

Fig. 1.—A small portion of the gut of the second specimen. Natural size.

Fig. 2.—Part of a transverse section of the wall of the gut of the first specimen. × 15 diameters. *I* internal, *E* external, surface.

Fig. 3.—Part of the same transverse section; × 350 diameters. *Per.* peritoneum; *Ml*, longitudinal muscle layer; *Mc*, circular muscle layer; *S.muc*, sub-mucosa; *Cc*, capsule of a cyst; *Sp*, spore contents of the cyst.

Fig. 4.—Several spores from the first specimen × 2,500 diameters.

On the Fish Parasites, Lepeophtheirus and Lernæa.

By Andrew Scott,

Resident Fisheries Assistant at the Piel Hatchery.

(With five Plates.)

Introduction.

There are comparatively few fishes that do not, at some period of their life history, prove on careful examination to be the host of at least one kind of parasite, either crustacean or worm. The worm parasites are usually found infesting the alimentary canal (Nematodes and Cestodes), the gills and skin (Trematodes and Bdellodes), while Crustacean (Copepod) parasites are almost entirely confined to places in direct communication with the exterior, such as the skin itself, the fins, the mouth, the branchial chamber, attached to the gills and operculum, in the nostrils, and in the mucous canals. They may even be found attached to the eye, as *Lernæenicus sprattæ* in the sprat (*Clupea sprattus*); and *Lernæopoda elongata* in the Greenland Shark* (*Acanthorhinus carcharias*), causing in the latter at any rate partial blindness; or burrowing into the abdominal cavity, as *Penella exocœti* in the flying fish† (*Exocœtus volitans*), till only the ends of the ovisacs are visible from the exterior.

The Copepod fish parasites have attracted much attention from Zoologists for a very long period, since the time when Aristotle, in his "Historia Animalium," tells us that the tunny and the sword fish are tormented by a sort of worm which fastens itself under the fin. Many of

* Mr. R. L. Ascroft, of Lytham, who visited Iceland on a "steam liner," fishing for halibut, &c., a year or two ago, says nearly all the sharks caught on the lines had these parasites in their eyes.

† One was exhibited at a meeting of the Liverpool Biol. Soc. in 1897, infested by two such parasites, recorded as *P. blainvilli*, which in turn were covered with a number of small Cirripedes.—Trans. L'pool Biol. Soc., vol. xi., p. xii.

the parasites now known to be Copepods were not at first recognised as Crustacea, chiefly because of the difficulty of making out the true characters and the absence of knowledge as to the life-histories. There was much difference of opinion even as to which were really the anterior and posterior extremities of these animals, due to the fact that the posteriorly placed ovisacs of the then known forms are cylindrical tubes which were by some supposed to be the antennules, and therefore that end was called the anterior. Hence many of the drawings of the earlier authors represent the animals standing on their heads.

Baird's "British Entomostraca," published by the Ray Society in 1850, marks an important epoch in our knowledge. This author gives an interesting historical account of the group, brings together all that was previously known, and gives a very full account, with excellent figures, of all the British species known at that time, and although some of these are inaccurate in detail, or have been added to by more recent investigations, still Baird's monograph is indispensable to any one working at the subject. Since 1850 comparatively little has been done in this country to increase our knowledge regarding the distribution or habits of these crustaceans. Within the past few years, however, the study has revived and some important papers, mainly speciographic, have been published.

The latest classification of the Copepod fish parasites arranges them under seven families, as follows:—ERGASILIDÆ, CALIGIDÆ, DICHELESTIDÆ, PHILICHTHYIDÆ, LERNÆIDÆ, CHONDRACANTHIDÆ, and LERNÆOPODIDÆ. With the exception of the PHILICHTHYIDÆ, all these families have representatives living on fishes found in the seas around our coasts.

These parasites vary considerably in size, ranging from one-thirtieth of an inch to nearly two inches in length. They also differ very much in shape. Some have their locomotor organs well developed, and are capable when necessary of leading a pelagic life for a period. Others have lost all swimming power, and become mere inert sacs, securely attached to their host by anchor processes, embedded in the tissues, and when taken off their host they soon die from want of food and oxygen.

The sexes are separate, the males as a rule being much smaller than the females. In many cases the males are practically parasitic on the females, especially those of the Chondracanthidæ and Lernæopodidæ. The fact that the males are found upon egg-bearing females of the above families is due to their power of locomotion having been lost when they reached maturity. When once they have settled down and matured they are unable to change their position to any extent. Fertilisation of the female is effected early in its life history, before the metamorphosis is completed. One copulation, apparently, is all that is necessary to fertilise the female for life. The resulting embryos remain attached to the external opening of the oviducts, either in a single or multiserial column, enclosed in a sac, until they hatch. The period of incubation extends over several weeks. The young parasites hatch out as nauplii, with three pairs of appendages. The nauplii undergo metamorphosis, which in some forms after a certain stage is reached is retrogressive, finally leading to the adult condition.

The Copepod fish parasites are generally regarded as being composed of about sixteen somites. Usually, however, some of these somites are suppressed or fused together, forming one compound segment, the true character of which is rendered evident by the appendages attached to it, each pair indicating a somite. At one end of the series, these parasites approach very nearly in structure and general appearance to the non-parasitic Copepods. At the other end they are extremely different, exhibiting most remarkable examples of retrograde development, and without a complete study of their life history it would be quite impossible to recognise them even as Crustacea.

In the following pages an account is given of the anatomy and metamorphosis of one member from each of the two very different families, the Caligidæ and the Lernæidæ, the forms chosen being *Lepeophtheirus pectoralis* and *Lernœa branchialis.*

The Caligidæ is the most extensive family of the Copepod fish parasites, and contains a larger number of genera and species than any of the others. As it stands at present, there are 124 species representing 25 genera. Three-fifths of the known species of Caligidæ belong to two genera, *Caligus* and *Lepeophtheirus.* Some earlier authors have not recognised the latter genus, and include the various species belonging to it in *Caligus.* There are, however, very important differences between the two which make their appearance early in life. These differences are constant, and give good cause for establishing a separate genus. *Caligus* has two semicircular suckers on the frontal margin of the cephalic shield, which are developed before the "chalimus"* stage is completed, and the biting part of the second maxillæ has only one tooth. In *Lepeophtheirus* these suckers are entirely absent all through life, and the biting part of the second maxillæ has two teeth. The changes that take place between the "nauplius" stage, when the animal is hatched from the

* The stage at which the animal first becomes attached to its host. (see p. 219).

egg, and the adult condition are practically the same in the two genera, and probably also in the other members of this family. From investigations carried on during the past two years, it may reasonably be concluded that *Lepeophtheirus*, throughout the remainder of its life and under normal conditions remains on the same fish that it attached itself to at the beginning of the "chalimus" stage. It is very rarely met with in tow-net collections. On the other hand, *Caligus* does not always remain on the same fish. At the completion of its "chalimus" stage it frequently leaves its host, and for a time leads a pelagic life. Tow-net collections often contain immature males and females, and occasionally mature males of *Caligus*, especially of *Caligus rapax*. Amongst these some may be found with a large notch in the middle of the frontal margin. This is due to the breaking of the chitinous filament by which they were secured to their host. The metamorphosis is a progressive one.

I.—LEPEOPHTHEIRUS (Müller).

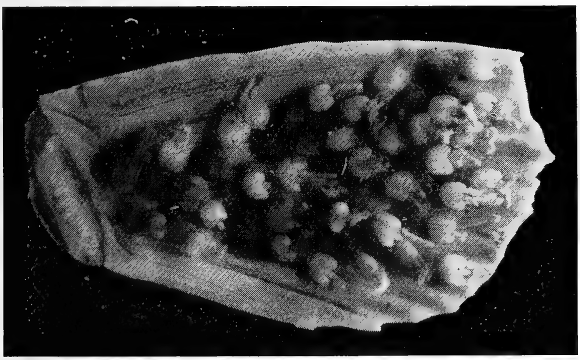
This species was first described by O. F. Müller* under the name *Lernæa pectoralis*.

Mode of Occurrence.

Lepeophtheirus pectoralis is most frequently found upon the "white fluke" or flounder (*Pleuronectes flesus*). It also occurs on the plaice, dab, sole, &c. It does not confine itself to any particular part of the exterior. Males and immature forms of both sexes are to be found all over the skin on each side of the fish. Mature egg-bearing females, however, are usually found under the pectoral, the pelvic, the ventral and the dorsal fins. With careful

* Prodrom. Zoolog. Dan., 1776.

examination it is possible to collect a series of these parasites, from the early "chalimus" stage to the adult condition, from one fish. Sometimes only a few specimens occur on the fish. At other times large numbers are to be found. It is by no means rare to find between twenty and thirty mature females under each pectoral fin alone, as in the case which is illustrated in the cut. One hundred specimens of another species, *L. hippoglossi*, have been collected from the "white" side of a halibut in the Aberdeen Fish Market. The average length of a mature



Lepeophtheirus pectoralis, 32 specimens, on the pectoral fin of a Flounder, from a photograph.

egg-bearing female is one-fifth of an inch, and of a male one-ninth of an inch. A mature female measures about one-tenth of an inch at its greatest breadth, and a male one-twelfth of an inch. These parasites attach themselves to the fish by means of their powerful second maxillipedes, assisted by the antennæ, and a decided pull has to be exerted before they can be torn away. By depressing the edges of the carapace and applying them closely to the skin, the parasite can increase its holding power to such an extent that the posterior end can be torn from the anterior part without detaching it. The anterior part, when thus separated from the posterior, retains its vital powers for at least twenty-four hours. At first it swims about vigorously, but after some hours begins to get sluggish in its movements, and then finally dies. The posterior part does not live long when separated from the anterior. The parasites can be kept alive in sea water for upwards of six weeks after removal from the fish.

External Characters.

The animal is depressed dorso-ventrally, and is of a more or less oval shape, and distinctly divided into four parts (Plate I., fig. 1). The foremost one of these parts, and usually the largest, is almost circular in outline, and has all the appendages, with the exception of the fourth and fifth pairs of feet, attached to it. This part is known as the cephalo-thorax.

Viewed from above, this region is seen to be slightly convex and divided into four portions by imperfect sutures. Two of these sutures are longitudinal, and separate the lateral parts of the region from the central. The remaining suture joins the centre of the two longitudinal sutures like the cross line of the letter H, dividing the centre of the cephalo-thorax into an anterior and a posterior portion, of which the anterior is the greater. There is also an apparent suture near the frontal margin. The frontal margin is indented, the greatest depth being in the middle line. This indentation to some extent is due to the scar caused by the breaking away of the filament for attachment in the "chalimus" stage. In the centre of the hollow, situated on the ventral surface, is an oval-shaped opening (*b*) with a chitinous fringe. This is evidently a sucker, and represents the remains of a median sucker which is considerably developed during the "chalimus" stage, when the maxillipedes are rudimentary. Probably in the adult it acts as a first aid in securing the animal to its host. Passing backwards from this sucker, but distinctly over it, there is a transparent rod (*c*, fig. 1, Plate I.; fig. 3, Plate III.), lying inside a triangular blood space, which terminates in a gland (*c g*, fig. 3, Plate III.). The gland is probably the organ that secretes the substance for the filament in the "chalimus" stage and the rod the remains of the filament. The filament and duct are in actual contact during the early part of the parasite's life (Plate I., figs 4 to 6, *c*). The eyes, two in number, are situated in the middle of the cephalo-thorax. The frontal and lateral margins are surrounded by a transparent membrane with faint transverse lines. This membrane is simply an extension of the chitinous exoskeleton which covers the whole animal. It has frequently a serrated edge caused by tearing.

The second part of the body is very small, and represents the fourth thoracic segment of the pelagic Copepoda. The fourth feet are attached to the external margins of this segment.

The third part of the body known as the "genital segment," is of variable shape, according to the degree of maturity of the reproductive organs. In an immature female (Plate II., fig. 6), it is usually very little larger than the fourth part, whilst in a mature one it is nearly as large as the cephalo-thorax. The genital segment of a mature female is somewhat quadrangular in outline, slightly wider posteriorly than in front. The same segment in a mature male (Plate I., fig. 2) is oval in shape and about one-third wider than the fourth part.

The fourth part of the body is short and narrow, being only one-fourth of the width of the female genital segment, and corresponds to the abdomen of the pelagic Copepoda. There is an incomplete articulation near the middle. At the apex of the abdomen there are two short papillæ known as the furca or caudal stylets, which usually have four or five plumose hairs on their posterior margins.

There are twelve pairs of appendages* (Plate II., fig. 1) as follows:—One pair of antennules, one pair of antennæ, one pair of mandibles, two pairs of maxillæ, two pairs of maxillipedes, and five pairs of feet, the first three pairs of feet only being adapted for swimming.

The eyes appear as a reddish spot in the living animal, and are situated on the dorsal surface mid-way between the frontal margin and the transverse line of the cephalothorax. When this spot is examined microscopically (Plate III., fig. 13) it is found to consist of two lateral eyes closely approximated, embedded in a mass of reddish-black pigment, and wholly under the carapace. Each eye has a simple, spherical, crystalline lens, beneath a thin cornea. Behind the lens is a row of retinal cells of fairly large size, lined internally with a tapetum or pigment layer. A chitin division lined with deep red pigment separates the two eyes. The earlier Zoologists had considerable doubt as to the true position of the eyes, some even believed the animals were blind. Others mistook the semi-circular suckers on the frontal margin of *Caligus* already referred to for the organs of vision, giving them the name "Binoculus."

The antennules are placed at the external margin, just behind the suture on the frontal plate, and each consists of two joints. The basal joint is much larger than the apical, and is clothed on its upper margin with plumose setæ.

* The minute details of the jointing and setæ of the appendages are not shown in these figures.

The other appendages are all on the ventral surface. The first are the antennæ. These consist each of two joints, a short stout basal one, and an apical one in the form of a strong prehensile claw. The antennæ are used to assist the second maxillipedes in grasping.* The apex of the claw projects into a small cup in front of the first maxillæ.

The mandibles are enclosed in the suctorial mouth (Plate II., fig. 8). They are stylet shaped, and composed of four joints. The apical joint of each mandible is flattened, curved inwardly, and serrated on its inner margin. There is no mandibular palp.

The appendages described here as the first maxillæ are given that name with some doubt. The pelagic Copepoda have only one pair of maxillæ, which correspond to the second pair in this memoir. The identification of the appendages now to be described as maxillæ is based upon the fact that they are innervated by a nerve from the sub-œsophageal ganglion that has its origin just anterior to the nerve supplying the maxillæ proper. The first maxillæ consist of one joint which is considerably swollen at the base, and tapers to a sharp point at the apex, forming as a whole a curved claw. Two minute setæ are attached to the basal part, and probably represent the exopodite or palp. These appendages are situated near the lateral margins, and slightly posterior to the base of the antennæ.

The second maxillæ are placed at the sides of the mouth, and consist of a single joint, robust at the base and dividing into two slightly curved teeth at the apex, representing the exopodite. There is a distinct endopodite, with two setæ at its apex, attached to the base of the anterior surface of the exopodite. The second maxillæ

* Baird (op. cit. p. 263) describes these organs as the first pair of footjaws.

appear to act as a scraping apparatus for removing the skin of the host.

The first maxillipedes consist of two-jointed appendages placed mid-way between the apex of the mouth, when it is at rest, and the lateral margin. Their chief function is apparently to keep the mouth free from obstruction.

The second maxillipedes situated near the middle line, mid-way between the first maxillipedes and the first pair of feet, are composed of two joints. The basal joint is considerably swollen and the apical is in the form of a powerful claw, which closes upon the basal joint, forming a strong grasping apparatus. According to Claus, and others, the first and second maxillipedes are really only the exopodite and endopodite of one and the same appendage.

The first three pairs of feet consist of an endopodite and an exopodite attached to a two-jointed protopodite. In the first pair the endopodite is rudimentary, and is represented by a single minute joint bearing a few setæ at its apex. The exopodite is two-jointed. In the second pair both the endopodite and exopodite are three-jointed. The third pair has the protopodite well developed, forming a lamella. The endopodite and exopodite are very small, the former being composed of two joints and the latter of three joints. Each of the first three pairs of feet is attached to a median sternal plate. The exopodite of the first, and the endopodite and exopodite of the second and third pairs, are provided with a number of plumose setæ along the internal margins of the joints. The dorsal and ventral margins of the protopodites of the second and third pairs of feet are furnished with movable setose plates. The sterna of the second and third feet are clothed with setæ on the posterior margins. The fourth pair of feet (Plate I., fig. 1) have two-jointed protopodites, and exopodites also two-jointed, but no trace of endopodites. The external angles of the joints are furnished with short spines. The fifth pair are rudimentary, are attached to the posterior end of the genital segment, and consist of a thin lamella, furnished with three setæ along the posterior margin. Situated on the middle line between the second maxillipedes is a strong chitinous plate with a bifid apex pointing posteriorly. This is known as the sternal fork, but its function is unknown.*

The external openings are the mouth, the vulvæ, the openings of the oviducts and vasa deferentia and the anus. The mouth (Plate II., fig. 1 and fig. 8) is situated on the ventral surface of the cephalo-thorax, and is placed at the apex of a short, movable, conical tube. This tube is composed of the upper and lower lips fused together. The vulvæ (Plate II., fig. 6) are situated on each side of the middle line near the posterior end of the genital segment, and communicate with the "receptacula seminis." They are difficult to see in the adult female, but have each frequently a spermatophore attached which indicates the position. The openings of the oviducts are in the same segment, but nearer the lateral margins and just under the fifth feet. The openings of the vasa deferentia (Plate II., fig. 5) are situated on the postero-lateral margins of the genital segment of the male. The anus is situated in the middle line at the apex of the abdomen. In addition to these more important openings, there are also apertures of pore-canals and glands on the anterior surface of the basal joint of the protopodites of the second and third pairs of feet, and also on the dorsal surface of cephalo-thorax and abdomen. The opening in some cases

* Mr. I. C. Thompson suggests that the sternal fork appears to him to be a support or crutch, serving to raise the body sufficiently from the host to enable either the swimming feet or the mouth organs to be used, but I have not seen it used in this manner.

is at the apex of a small papilla, and communicates with a sac in the interior (Plate II., fig. 11).

When resting, *Lepeophtheirus* lies upon the ventral surface, keeping the first three pairs of feet moving with spasmodic jerks. When irritated, as in attempts to remove them from their host, the males and immature females move very rapidly over the skin of the fish. The mature females make no attempt to escape, only clinging more securely. On transferring them to clean sea water they settle on the sides and bottom of the vessel, and sometimes adhere to the surface film of the water, remaining quiescent for long periods. When the water is shaken slightly they detach themselves and swim about rapidly on their backs. They soon tire, however, and return to rest again. *Lepeophtheirus* makes no attempt to leave the water when kept in small aquaria. The allied form, *Caligus*, on the other hand, crawls out of the water and up the sides of the glass, where it remains, making no attempt to return, and soon dies owing to the evaporation of the water from under the carapace. These parasites are very tenacious of life, and live for a considerable time after the host has died if they are not allowed to dry up. In some instances, although the host had been dead over twelve hours, and the parasites to all appearance were also dead, they soon revived when placed in sea water. Increase of temperature to 16° C. and over is fatal to them. They can, however, stand very considerable decrease of temperature. On one or two occasions during February, 1900, the small aquaria in the tank room at Piel, some of which contained parasites under observation, were frozen, and the temperature of the room itself stood at —1° C., but the parasites suffered no harm. They can also be kept alive in sea water for weeks without change if the aquaria are kept cool.

The colour of the living animal varies with the position in which it lives. On the dark side of the fish they are of a deep brown, almost black, colour. On the "white" side and under the fins they are nearly colourless, due to the contraction of the pigment cells, which appear as brown spots under the microscope. The dark coloured forms soon become almost colourless when exposed to light.

The Body-wall and Body-cavity.

The body-wall consists of (1) the chitinous cuticle or exoskeleton, which has been described in the external characters, (2) the cellular hypodermis, and (3) the connective tissue laminæ which line the integument, traverse the body cavity, and support the alimentary canal and other organs. The only cavity left inside the body-wall is the system of lacunæ, in which the colourless blood flows (see below under blood system, p. 20).

The Alimentary Canal.

The mouth, already described, leads into a short, narrow curved œsophagus, lined with a thin chitinous coat which is continuous with the exoskeleton. Near the anterior end the chitinous coat is much folded. The œsophagus (Plate III., figs. 3 and 5) passes through the anterior part of the nervous system, and in a transverse section of that region appears as a minute pinhole. After leaving the nervous system, it courses over the sub-œsophageal ganglion, and under a short cæcal projection of the stomach, finally entering the stomach on its ventral aspect, at the posterior end of the sub-œsophageal ganglion.

The stomach lies along the ventral surface, and is lageniform in shape (Plate II., fig. 3). At the anterior end it is produced into a short cæcum which extends over the posterior end of the œsophagus and it terminates by opening into the intestine in front of the second pair of feet.

The intestine is the direct continuation of the stomach. It commences in front of the second pair of feet, and passes through the thoracic and genital segments into the abdomen. It widens slightly behind its junction with the stomach, and then contracts as it passes through the fourth thoracic segment. It expands again in the genital segment, and contracts as it enters the abdomen. It terminates in a short rectum leading into the anus at the apex of the abdomen. There are no convolutions in this alimentary canal.

The intestine at its anterior end lies on the ventral surface of the animal. In the centre where it passes through the genital segment, it courses along the dorsal surface. It bends down as it approaches the abdomen, and occupies the centre of that part of the body. In transverse sections of a mature female the stomach is triangular in shape, with the apex pointing dorsally. The intestine in the genital segment is also triangular in transverse section, but the apex is directed ventrally. In immature females the stomach and intestine are of almost circular outline when cut transversely, so that the alimentary canal is considerably compressed when the reproductive organs arrive at maturity.

The wall of the whole alimentary canal is lined with a thin layer of chitin continuous with the exterior. In many places it is considerably broken up, giving it the appearance of fine striation. Underneath the chitin is a layer of nucleated cells, which extends from the posterior portion of the œsophagus to the rectum. There does not appear to be any marked regional differentiation in the cells. The lining of the stomach and intestine is thrown into a number of longitudinal folds (Plate III.,fig. 11), the height of which varies considerably. In the anterior portion of the stomach these folds are very little higher than the general line, but as they pass posteriorly they increase considerably, diminishing again in the intestine as they approach the rectum. The greatest height of the folds is reached in the portion of the intestine passing through the genital segment. In the intestine and posterior portion of the stomach there are a number of glandular cells, usually at the apices of the longitudinal folds, the contents of which stain deeply with eosin. In many of these the cell contents have disappeared, leaving a clear space, only the cell wall remaining.

The wall of the stomach and intestine is marked by a series of transverse constrictions, giving it a crenate appearance, which is easily seen in the living animal. In the living animal an intermittent movement of the intestine and stomach is kept up. The action is wave-like, starting at one end, and passing to the other. After continuing in one direction for a time, it reverses and passes the opposite way. There is no valve between the stomach and intestine, and when the peristaltic motion is reversed the fluid in the intestine is sent back into the stomach again. The only portions of the alimentary canal that can be closed are the œsophagus and anal end of the rectum. The former is controlled by two longitudinal muscles which compress it, the latter by a number of muscles passing obliquely to the body-wall at the sides of the abdomen. The fluids contained in the alimentary canal are usually colourless, but occasionally when taken direct from the fish and placed under the microscope, a reddish tint may be detected at the posterior end of the œsophagus.

In connection with the alimentary canal there is a distinct paired digestive gland (Plate II., fig. 3 and fig. 9).

It consists of three portions, two moderately large masses on the lateral margins of the cephalo-thorax, just behind the antennules, and a median, smaller one, in front of the base of the mouth. The lateral portions are connected with the median by a duct. The median portion gives off a duct, which passes posteriorly along the œsophagus and enters the cæcum at the anterior end of the stomach. When the parasite is first removed from the fish the digestive gland is usually of a dark brown colour, but after starving for a few weeks it becomes colourless. The product of the gland is a pale, yellow fluid, which can be seen as it passes along the duct between the lateral and median portions.

Situated between the first and second pairs of thoracic feet is a pair of glands visible in the living animal as brown spots. A minute duct passes downward and then forward along the stomach. The duct appears to enter the stomach near the posterior end.

The food of this parasite is said to be mucus, and blood has not been detected in the stomach.* This fact gives some cause for the opinion advanced by many Zoologists that *Lepeophtheirus* and other allied genera are therefore not parasites in the strict sense of the term, and may not be hurtful to their hosts. There is considerable difficulty in settling the question of their true food. Specimens taken direct from the living fish and placed under the microscope, rarely show even the faintest trace of red colouring matter in the alimentary canal. The difference in structure between the Caligidæ and the obviously blood-sucking Lerneæ is very great. This will be pointed out in the section dealing with *Lernœa branchialis*, and may account for the apparent absence of blood. Mucus at the best is a poor food, but *Lepeophtheirus* can live for upwards

* They do not hesitate, however, to eat their comrades when these become feeble.

of six weeks in filtered sea water without visible food of any kind.

From the large numbers of flounders examined in the Piel laboratory, partly in connection with this memoir, but chiefly in connection with fisheries work, during the past year or two, the conclusion has been arrived at, that *Lepeophtheirus pectoralis* to some extent feeds on blood, and may be hurtful to the fish, especially when present in numbers (see figure on p. 6).

The appendages are more suited for a sedentary life than even a semi-pelagic one. The animals can only remain swimming for short periods, and their presence in tow-nettings, therefore, is accidental. They do not, under normal conditions, and as long as the fish remains in a healthy state, leave their host. In the fish tanks at Piel over 150 flounders, all more or less infested with *Lepeophtheirus*, are kept during the spawning season. The waste water from the tanks is carefully filtered for periods of at least three months in the spring, to collect the eggs shed by the fish. Yet not even one specimen of the parasite has been found in the filter. When the fish are examined and the parasites removed, no matter how carefully, the skin, especially where there are a number close together, is usually lacerated and bleeding. The males and immature females on the general surface of the body do not seem to remain long enough in one place to cause obvious injuries. Under the fins, however, and on the fins themselves, where the egg-bearing females are usually found, and where they lie for weeks in the same position if not disturbed, is the part of the fish chiefly injured. The pectoral fin in some instances may be partially destroyed, and pieces of the tissues are frequently found enclosed in the second maxillipedes of the parasite.

The antennæ and claws of the second maxillipedes are plunged into the tissues of the fish along with the teeth of the maxilla, lacerating the skin, and into this wound the suctorial mouth is directed. The blade-like mandibles assist in collecting the particles of food material. These are sucked up, pass down the œsophagus into the stomach, where they are at once acted on by the fluid from the digestive glands, and the colour of any blood present may then be discharged. It is usually at the junction of the œsophagus with the stomach that any red coloured particles occur. The food can then be traced along the stomach and intestine, and the waste matter is expelled from the anus in long strings.

On comparing transverse sections of the alimentary canal of *Lepeophtheirus* and of *Lernæa* which happen to contain food, and have been stained in eosin and hæmatoxylin, there is seen to be a marked similarity in the nature of the food in the two cases. Both are finely granular, and stain red with eosin. Mucus from the flounder has no such granular appearance.

It is stated by some Zoologists that copepod parasites are generally found most abundantly on weak and diseased fishes. It is not so with *Lepeophtheirus pectoralis*. Flounders with many parasites in our tanks were in as good condition as those that had none. They were never found on flounders which were thin and in poor condition, as they detach themselves and swim away when the fish becomes feeble. This was proved by actual experiments and observations at the Piel Hatchery.

The Blood and Circulation.

There is no heart in *Lepeophtheirus*, nor are there any proper blood vessels.

The circulation is wholly lacunar, and simply consists of broad, irregular streams passing through the spaces left among the internal organs, and between the connective-tissue bands of the body-wall. These streams have in general certain definite directions, but they are not uniform, continuous currents. The fluid advances by successive jerks, depending upon the movements of the alimentary canal and, in part, of the reproductive system. The blood is a clear fluid, containing numerous colourless corpuscles. The corpuscles vary in size and shape, and can accommodate themselves in diameter to the spaces through which they pass.

Plate II., fig. 2, shows the course of the main blood currents. Starting from behind the eye, there are two currents passing posteriorly, one flowing to each postero-lateral angle of the cephalo-thorax, where it turns and courses forward along the lateral margin of the carapace till it reaches the group of muscles connected with the mandibles. It then divides, one portion continuing along the margin to the base of the antennules, where it splits up into minute currents, all converging to the base of the mouth, while the other branch of this cephalo-thoracic current passes along the muscles of the mandibles and duct of the digestive gland, and meets the currents of the former branch at the base of the mouth.

A second main current courses posteriorly through the cephalo-thorax and the fourth thoracic segment, into the genital segment. It flows there along the reproductive organs in a broad stream, and turns round at the end of the segment. The currents from both sides meet in the middle line, and flow forward under the alimentary canal. In the region of the second maxillipede, this median ventral current breaks up into a complicated series of smaller currents, some of which pass into the two currents flowing posteriorly, and the others into the currents passing to the base of the mouth.

The main currents are easily seen by placing the living animal on its back, in a drop of sea water on a slide, then covering with a thin cover glass and examining with a $\frac{1}{4}$in. objective.

The blood currents described above do not continue to flow for any length of time in the one direction. At one period they may be flowing as indicated by the arrows in Plate II., fig. 2. Then they suddenly slacken and reverse, and stream for a time in exactly the opposite course. Sometimes the blood corpuscles are seen to simply oscillate backwards and forwards, making no advance, but at other times they pass rapidly along in a definite manner.

There are no independent organs of respiration. It has been suggested by Hartog and others that the blood is probably aerated from the sea water contained in the thin-walled alimentary canal by the method of "anal respiration," which has been described in *Cyclops*, *Caligus*, *Argulus*, *Daphnia*, *Cypris* and other lower Crustacea.

The cuticular exoskeleton over the surface of the body is in most places so thick that the respiratory change of gases may be supposed to take place much more readily through the very thin layer of chitin which lines the rectum. There are dilator muscles attached to the wall close to the anus, and the peristaltic movements of the whole alimentary canal may aid in the production of inhalent and exhalent currents of water. It appears, however, to the present author that further precise observations are required to substantiate this hypothesis.

No organ corresponding to the "shell gland" described in various lower crustacea, and shown by Claus, Hartog and others to be a renal organ, has been found.

The Muscular System.

The muscles moving the appendages and segments of the body can be distinctly seen and traced to their extremities through the transparent exoskeleton (Plate II., fig. 1 and fig. 2).

The frontal portion of the cephalo-thorax is controlled by two short slender muscles, *mlf.*, (Plate II., fig. 2) passing postero-laterally from near the lateral edge of the carapace. They act in depressing the margin so as to produce a close attachment to the host. The posterior region of the cephalo-thorax is supplied with a number of pairs of muscles, some passing forward and others laterally, which contract and expand that part of the body. The lateral margins are controlled by long muscles passing obliquely outwards from the anterior end of the lateral suture. The muscles of the fourth thoracic and genital segments arise near the median line of the posterior portion of the cephalo-thorax, and pass backwards. They produce a lateral motion of the posterior parts of the body, and also a sort of telescoping contraction which draws the genital segment into the cephalo-thorax. The muscles of the abdomen arise near the middle of the genital segment and pass backwards. They produce a telescoping movement of the abdomen.

The various appendages and other organs are also well supplied with muscles. The antennules have each a pair, which elevate and depress the joints. The grasping action of the antennæ is produced by muscles passing obliquely to the lateral margins. The movements of the mouth are controlled by a complicated series of muscles passing anteriorly, posteriorly and laterally, all of which assist in elevating and depressing it when sucking up food. The mandibles are provided with muscles of extraordinary length and power, which pass obliquely backward to the lateral margins of the carapace nearly opposite the first pair of feet. The muscles of the first maxillæ are very short and thin. They pass along the posterior surface of the muscles of the antenna, to the lateral margins. The second maxillæ are controlled by powerful muscles passing to the lateral margins. The muscles of the first maxillipedes pass obliquely forward to the lateral margins. The second maxillipedes are supplied with short and powerful muscles which pass forward under the second maxillæ. The terminal claw is provided with muscles of great strength. The first three pairs of feet are supplied with a complicated series of muscles passing dorsally amongst those controlling the posterior portion of the cephalo-thorax. The fourth pair of feet are apparently little used, and consequently are only supplied with feeble muscles. The alimentary canal is controlled by longitudinal muscles, and also by muscles passing transversely, which produce the wave-like peristaltic motions and crenated appearance. The anus is opened and shut by muscles passing obliquely, which open and shut each side alternately or simultaneously according to the requirements of the animal. The reproductive organs are also controlled by muscles, which give rise to pulsating movements, and assist in expelling the ova and spermatophores.

The Nervous System.

The central nervous system in *Lepeophtheirus* consists of a cerebral or supra-œsophageal ganglion and a large sub-œsophageal ganglion placed on the ventral surface, in the median line, and extending from slightly in front of the second pair of maxillæ to near the articulation of the second pair of maxillipedes with the body. The ganglia are connected by broad commissures passing on each side of the œsophagus, leaving only a narrow opening for its passage. The sub-œsophageal ganglion projects slightly forward under the supra-œsophageal, giving it the appearance of being separated from it, when viewed from the ventral aspect (Plate III., fig. 2). These are the only ganglia, and they supply the various parts of the body with nerves.

The supra-œsophageal ganglion is about half the size of the sub-œsophageal. It is produced on its dorsal surface into an optic lobe (Plate III., fig. 5), from which arises a distinct pair of optic nerves. Horizontal sections of the optic lobe show that the roots of these nerves cross each other (Plate III., fig. 12). Each optic nerve, therefore, is supplied by fibres from both sides of the brain.

The nerves supplying the antennules arise from near the anterior angles of the ganglion. They pass obliquely forward to the base of the antennules, and there subdivide into a number of branches which pass to the setæ clothing the anterior surface of the basal joint and apex of the second (Plate III., fig. 4). From the manner in which the antennules are supplied by this nerve it is evident that they are important sensory organs (Plate III., fig 4).

The antennæ are supplied by nerves arising from the anterior angles of the ganglion, which pass anteriorly under the nerves of the antennules and enter the base of the antennæ. These are the only appendages supplied from the supra-œsophageal ganglion.

The sub-œsophageal ganglion is heart-shaped, and fully twice the size of the supra-œsophageal. It represents the whole of the thoracic and abdominal ganglia of the higher crustacea, and supplies the remainder of the appendages.

The nerves passing to the mandibles have their origin on the anterior margin near the middle line. They course along the muscles of the œsophagus, and reach the mandibles near the base of the mouth.

The next pair of nerves arise at the anterior angle of the ganglion, course forward, under the nerves of the antennæ and antennules, to the frontal plate which they enter about midway between the lateral margin and middle line. They then turn abruptly and pass out to the lateral margins of the frontal plate, just above the antennules. The margin at this point is destitute of the transparent membrane which surrounds the carapace. The nerves terminate in a shallow cup, evidently a sensory organ.

Three other pairs of nerves arise from the anterior angles of this ventral ganglion. The first passes to the rudimentary first pair of maxillæ, the second, a short nerve, passes to the second pair of maxillæ, and the third to the muscles controlling the lateral margins of the cephalo-thorax.

The nerves supplying the first pair of maxillipedes arise from the anterior portion of the lateral margin. They are large nerves at their origin, but immediately divide into four branches, passing to the maxillipedes and muscles. The second pair of maxillipedes are also supplied by nerves arising from the lateral margins. Like those of the first maxillipedes they have strong roots, and at once divide into three branches which pass to the second maxillipedes and their muscles.

The remaining nerves have their roots in the posterior end of the ganglion. There are three pairs. These supply the five pairs of feet and the abdomen. The outer pair of nerves supply the first pair of feet. Near the origin a branch is given off which passes to the muscles of the stomach. The next pair supply the second pair of feet. They course along the median nerves as far as the sternal fork and then diverge. Just under the sternal fork a branch is given off which appears to pass to the muscles of the posterior region of the cephalo-thorax.

The median pair course close together, and unless carefully examined are easily mistaken for a single nerve. There is a distinct division, however, which is apparent even in the roots. Between the second and third pairs of feet a strong branch is given off which passes to the third pair of feet. The nerves then diverge, and just before entering the fourth thoracic segment give off a branch that passes to the fourth feet. The main trunks course on through the genital segment, still further diverging. Shortly after entering the broad part of this segment a third branch is given off which takes a semi-oval course along the ventral surface of each half of the segment, finally passing to the setæ of the fifth feet. On entering the abdomen the main trunks split into two branches, one passing to the anus and the other to the setæ on the apex of the caudal stylets (Plate III., fig. 2).

Each nerve, after leaving the main trunk, sends out numerous branches which pass to the various muscles controlling the appendages innervated by that nerve. Excepting the nerve passing to the fifth feet, the branches are not shown in the figure (Plate III., fig. 1). There is considerable difficulty in tracing the endings of the branches when they pass amongst the muscles.

The chief sense organs connected with the nervous system are the conspicuous eyes which are described above (p. 71). There are also the numerous setæ scattered over the surface of the body and appendages, which are possibly tactile in function. Probably the setæ upon the antennules, which are richly supplied with nerves from the supra-œsophageal ganglion, have a special function, which may be olfactory.

The Reproductive Organs.

The reproductive organs are paired, and as already stated, the sexes are separate.

In the female (Plate II., fig. 4) the ovaries are large kidney-shaped organs lying on each side of the anterior portion of the stomach and extending from under the first pair of feet to the base of the second maxillæ, when fully matured. Each oviduct (*od.*) arises near the anterior end of the ventral surface of the ovary, and courses posteriorly as a narrow tube till it enters the genital segment. It then expands rapidly, and passes to near the end of the segment. It then reverses its course, passing forward to the central portion of the segment, where it turns again in a posterior direction, and passing out to the centre of each half of the segment, it opens to the exterior just under the fifth feet. Each oviduct thus forms two loops in the genital segment. On the ventral aspect of the loops of each oviduct there is a short, semi-transparent cylindrical tube (*sg.*) with the anterior end closed and rounded, and the posterior produced into a fine duct, which communicates with the oviduct near its extremity. This organ is evidently a cement gland for secreting the enclosing membrane of the ovisac. Each vulva (fig. 6, *vu.*) is situated near the middle line behind the junction of the genital segment with the abdomen. It appears to consist of a simple opening leading into the vagina which expands into a "receptaculum seminis." This is an elongated sac passing from the median line to the oviduct, which it enters alongside the duct of the cement gland.

In the male the reproductive organs (Plate II., fig. 5) consist of a pyriform testis, on each side, situated in a position corresponding with that of the ovary. It is only about one-fourth the size of the ovary. Each vas deferens courses posteriorly into the oval genital segment. It communicates with the sac of the spermatophore on the external margin near the posterior end. A short cement gland furnishes a duct which passes in at the anterior end of the sac. The spermatophore, an oval body containing the spermatozoa, is expelled from an opening near the posterior angle of the segment.

In *Lepeophtheirus* the fertilisation of the female is accomplished soon after the "chalimus" stage is completed. The genital segment is then very small, about one-fifth the length of that of a mature female. It is grasped by the male on the dorsal aspect. The antennæ close round the junction of the genital segment with the fourth thoracic, and the second maxillipedes seize the segment immediately in front of its junction with the abdomen. The animals remain in this condition for some time, and can only be separated with difficulty. The spermatophores are discharged in pairs. When they are ready for discharging the male folds the whole of the posterior portion of its body along the ventral surface of the female. The openings of the spermatophore sacs are thus brought in contact with the vulvæ. The spermatophores are then discharged, and being in a viscid condition, at once stick to the female. One end of the covering, probably the last part that leaves the opening, is drawn out into a fine thread, which helps to secure the spermatophore. The spermatophores are not, apparently, always fortunate in reaching the vulvæ. It is by no means uncommon to find them planted amongst the appendages in little clusters like grapes. These have been mistaken by some of the earlier Zoologists for the eggs. when the true egg sacs were considered to be antennules.

One copulation apparently fertilises all the eggs produced by the female. It is obvious, when one compares the male with a mature female (Plate I., figs. 1 and 2), that fertilisation cannot be accomplished when the female genital segment is fully developed. Hence the need of it being effected at an early stage.

The exact period at which the eggs are fertilised by the spermatozoa is unknown. The spermatophores may be found attached to the body for some time after the female has begun to produce eggs (Plate II., fig. 4, *sp.*), but they are then simply empty sacs. Plate II., fig. 7, shows a pair of spermatophores that have been detached from an egg-bearing female. The little opening at *d.* was in direct communication with the vulva. These sacs were empty. In an immature female (Plate II., fig. 6), the vulva leads into a short vagina, passing directly into the oviduct. The spermatozoa probably remain in the vagina which becomes a "receptaculum seminis." In transverse or longitudinal sections through the region of the vagina of a mature female masses of spermatozoa are frequently found in the swollen part (Plate II., fig. 4, *rep.*). The oviduct in the immature female has no communication with the exterior except through the vulva.

The ovary of a mature female appears as shown in Plate II., fig. 10. It consists of a number of tubules lined with nucleated cells representing a germinal epithelium, which will form the eggs. The interior of the tubules is filled with a granular substance, staining faintly blue with hæmatoxylin and eosin. When the eggs become mature the walls of the tubule break down and the eggs pass out into the oviduct. They are then very small, about ·02 mm. in diameter, and do not fill up the duct. They are simply nucleated cells. As they pass posteriorly they increase in size. In the fourth thoracic segment they measure ·06 mm., and appear as oval bodies with a thin vitelline membrane. The cell contents are finely granular. The nucleus is a large oval body, with a sharp outline. A single rounded nucleolus is also present. After passing into the genital segment the cell contents increase in amount, causing a great enlargement of the egg, which finally passes out at the opening between the vulva and the lateral margin of the segment, already described. As the eggs pass out they are probably fertilised by the spermatozoa from the "receptaculum seminis." They are then enclosed in a thin chitinous tube, secreted by the cement gland, which gradually extends as more eggs are expelled. The ovisacs are often longer than the animal. The eggs in this tube are biscuit-shaped, measuring ·36 mm. in diameter and ·11 mm. in thickness. They are arranged in a single column. When the animal is irritated the tubes are frequently detached. When the embryos hatch, the empty, ruptured tube is left, and remains attached to the animal for a time. After examining many specimens, the conclusion has been come to that additional eggs are not developed in the tubules of the ovary after the first lot have been expelled. Adult females in which the ovary is only an empty sac are not uncommon.

Life History.

Lepeophtheirus has no regular breeding season. Mature females with ovisacs may be found at all times. The state of development reached by the embryos carried by various females collected at the same time is frequently widely different. In some the germinal disc has just begun to segment, in others the larvæ are ready to hatch.

The changes that take place in the developing embryo have not been worked out by the author. The period of incubation was found to extend over several weeks at least. In one case the ovisacs were kept for six weeks, and in another eight weeks, before the embryos hatched. The incubation takes longer than that, however. In both cases the embryos were pigmented when placed under observation. The first appendages that make their appearance are the antennules, antennæ and mandibles. They are in a rudimentary state, and the embryo is now ready to hatch. During this period the embryo increases in size as it develops.

The whole of the embryos contained in the tube hatch practically at once. The enclosing membrane ruptures, then the membrane of the tube splits, and the nauplii after freeing themselves from the fragments swim to the surface. Plate I., fig. 3, represents a newly hatched nauplius, the natural size of which is ·46 mm. It leads a pelagic life for a time, and grows by successive moultings. It next settles down on some fish, and passes into a cyclopoid state (Plate I., fig. 5). The young parasite immediately develops a thin chitinous filament from the median frontal gland already described, which passes into the tissues of the host, and it becomes fixed. The median sucker (*b.*, Plate I., fig. 5), with the help of the rudimentary antennæ and second maxillipedes, enables the animal to bring its mouth into contact with the host.

If young plaice, flounder, cod, &c., one to three inches in length, be examined very carefully at the end of the summer, it is practically certain that some recently attached *Lepeophtheirus* or *Caligus* will be found either on the fins or some other part of the integument. On examining fins which have parasites attached, the filament is seen passing through the skin, under it, and along one of the fin rays, as shown on Plate I., fig. 5 (natural size ·77 mm.). The filament may have the end bluntly pointed or flattened into a disc (Plate I., fig. 4). This is the "chalimus" stage referred to on previous pages, so called because Burmeister, in 1831,* described it as a new genus under the name "Chalimus." This was afterwards shown by Hesse and others to be only a young stage of the Caligidæ. The young parasite continues to grow by successive moultings, and the various appendages make their appearance in regular order. The duration of this attached stage has not been determined. When the appendages are fully developed, as in Plate I., fig. 6, the filament separates at its junction with the frontal margin leaving a notch, the remains of which persist all through the adult life.

The male, at the conclusion of the attached stage, is practically fully developed. The female remains in an immature condition until fertilisation is effected and the ova begin to pass down the oviducts. The genital segment then increases in size from that shown on Plate II., fig. 6, to the mature condition of Plate I., fig. 1.

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* Nov. Act. Acad. Natur. Cur. Bonn., vol. xvii., p. 294

II.—LERNÆA.

The Lernæidæ, although not so extensive a family in numbers of genera and species as the Caligidæ, are more interesting to the specialist. They present some of the most remarkable instances of retrograde development that are to be found in the whole group of parasitic Copepoda. There is great excuse for the difficulty experienced by the earlier Zoologists in giving certain members of this family their true place in the animal kingdom. The fact that these animals were placed first in one group and then in another by successive workers is not surprising, considering that nothing was then known about their life history. It requires some study even at the present day to show that *Lernæa* is a Crustacean, still more to demonstrate that it is related to *Lepeophtheirus*.

The genus *Lernæa* as it now stands contains only five species. Formerly it was very extensive, and included many forms, such as *Lepeophtheirus pectoralis*, that had not the least apparent resemblance to each other in the adult state. Careful research, along with a better knowledge of the minute structure, gradually eliminated the unlike species, which were removed to other genera. An excellent historical account of our knowledge of the group will be found in Baird's "Entomostraca."

The species described here is *Lernæa branchialis*, Linn.

Mode of Occurrence.

The adult female is found on the gills of the Gadidæ, such as cod, haddock and whiting. Immature (cyclops stage) males, and females with adult males attached, are found on the apex of the gill filaments of the flounder, sometimes in large numbers. Full-grown females are not plentiful on the fishes caught in the vicinity of Piel.

Two to four specimens have been found after examining numerous catches of young cod of one dozen each. The ratio thus varies from one in three fish to one in six. In one or two instances two and sometimes three specimens were found on young cod eight inches long. The length of a full grown female *Lernæa* is a little over one inch.

The adult female is securely fastened to its host by strong branched horns, three in number, which are buried in the tissues of various parts of the gill arches. In many instances the head was found to have actually penetrated the ventral aorta. To obtain the specimens in an entire condition the tissues of the host have to be carefully dissected. Attempts to remove them by force always result in the head being left in the fish. The parasite, when once fixed, remains in the same position throughout life. When it dies the softer parts decay, but the head continues for a long time embedded in the tissues of the host, and is often met with there when dissecting out living specimens.

External Characters.

The adult female (Plate IV., fig. 1) is cylindrical. It is unsegmented, but roughly divided into three parts—a globular head with anchor-like processes, connected by a narrow neck to a much swollen posterior part.

The globular head corresponds to part of the cephalo-thorax in *Lepeophtheirus*. It is furnished with three more or less branched horns, two lateral and one median and dorsal. The head is slightly curved downwards, terminating in a conical apex.

The anterior portion of the neck represents the remainder of the cephalo-thorax and the fourth thoracic segment. The whole of the neck is marked by fine transverse lines.

The remainder of the neck and the greater part of the swollen mass behind corresponds to the genital segment. The abdomen is represented by the terminal portion of the swollen part, and gradually tapers to a blunt end. The swollen region of the genital segment is abruptly bent into the form of the letter S (Plate IV., fig. 1).

The appendages are rudimentary, the greater number being entirely absent. Those present are the first pair of maxillipedes placed at the apex of the head, immediately under the mouth, and four pairs of swimming feet at the anterior end of the narrow neck. The swimming feet are exactly as they exist in the cyclops stage both in size and structure. The protopodite is two-jointed, the exopodite of the four pairs is two-jointed. The endopodite of the first two pairs is also two-jointed. The third and fourth pairs of feet have no endopodite.

The external openings are, the mouth placed at the apex of the head, the openings of the oviducts situated on the ventral aspect of the S-shaped region, and the anus at the blunt apex of the abdomen (Plate IV., fig. 1, *an.*).

The colour of the living animal is dark red, due to the contained blood. When removed from the fish and placed in sea water the colour changes to white. *Lernæa* does not live long after being taken from the fish. The longest period observed was about twelve hours. They are simply inert sacs quite incapable of movement. Occasionally the parasites are covered with colonies of hydroids which sometimes entirely obscure them. The exoskeleton consists of a chitinous cuticle moderately thin and soft in the region of the swollen part, but thick and hard on the neck and head.

Immature *Lernæa branchialis* living on the apex of the gill filaments of the flounder (Plate IV., figs. 3, 4, and 5) are cyclopoid in appearance. The animal is oval in transverse section. It is composed of five distinct parts—an oval cephalo-thorax, three thoracic, and one terminal segment, representing the genital segment and abdomen. The anterior portion of the genital segment in the female is indistinctly divided into eleven joints.

The cephalo-thorax attains its greatest width just behind the eyes; beyond that point the sides converge until they reach the first thoracic segment. The cephalo-thorax is produced anteriorly into a broad blunt rostrum. In the very early cyclops stage (Plate IV., fig. 3), the rostrum is further produced into a short triangular filament which secures the parasite to its host. The eyes (Plate V., fig. 3) are situated on the dorsal surface a short distance behind the rostrum. In the living animal they appear as a dark red spot with a crystalline lens projecting slightly at each side. When examined microscopically the structure is found to be the same as that described in *Lepeophtheirus.* A thin cornea encloses a spherical crystalline lens. Behind the lens a row of fairly large retinal cells is lined internally with a tapetum layer. A chitinous septum lined with deep red pigment separates the two eyes. The appendages attached to the cephalo-thorax are as follows:—

The antennules are placed at the posterior angles of the lateral margins of the rostrum. They are short, and are composed of four nearly equal joints furnished with fine setæ.

The antennæ are composed of two joints. The apical joint is provided with a strong claw on its external angle. The antennæ usually project beyond the rostrum, and it is by means of these that the attachment to the host is maintained when the filament is broken off.

The mandibles are not enclosed in the suctorial mouth. They are situated at the base of the lateral surfaces of the conical tube of the mouth, and consist of two parts. The basal joint is cylindrical. The second joint is flattened, and terminates in a broad blade, which is serrated on the inner margin.

The single pair of maxillæ are placed at the base of the mandibles. They consist of two lobes, one of which is very small. The larger lobe has two moderately long setæ at its apex, the smaller one has one seta.

The first pair of maxillipedes are placed immediately behind the mouth. They consist of four joints, the last joint being furnished with a strong claw. The basal joint has two short hooks near its apex.

The second pair of maxillipedes in the female are rudimentary, and are represented by a minute knob. In the male they are composed of two joints, the apical one being in the form of a powerful claw. It is by the aid of the second maxillipedes that the male grasps the female during copulation.

The first pair of swimming feet consist of a two-jointed protopodite, an endopodite and an exopodite, both two-jointed. The apical joints of the endopodite and the exopodite are furnished with long plumose setæ on their inner margin and apex. This pair of feet is attached to the posterior end of the cephalo-thorax.

The second pair of swimming feet is attached to the first free thoracic segment, the third pair to the second free thoracic, and the fourth pair to the third. These free segments really represent the second, third and fourth thoracic segments, the first being a part of the cephalo-thorax. The second pair of swimming feet in every respect resemble the first pair. The protopodites of the third and fourth pairs are two-jointed; the endopodites in both pairs are absent. The exopodites are similar to those of the first and second pairs. The fifth pair of feet is represented by minute papillæ. The caudal stylets are very short, and furnished with three or four short plumose setæ at the apex.

The external openings are the mouth, the vulvæ, the openings of the vasa deferentia and the anus.

The mouth is situated on the ventral surface of the cephalo-thorax, at the apex of a conical tube, composed of the upper and lower lips fused together. In the very early cyclops stage the lips are not fused. The vulvæ and openings of the vasa deferentia are placed at the posterior angles of the genital segment. The anus is at the apex of the abdomen, in the middle line. The vulvæ open into the receptacula seminis, which are in direct communication with the oviducts.

The whole of the genital segment and abdomen in the female is marked by fine transverse lines. The colour, which is arranged in patches, varies from dark violet to light red.

Alimentary Canal.

In the adult the mouth opens into the intestine, which probably acts as the stomach, the œsophagus and true stomach having disappeared in the metamorphosis of the cephalo-thorax. The intestine is at first narrow where it passes through the neck, then it widens considerably in the swollen part of the genital segment, contracting slightly in the abdomen, and finally terminates in a short, narrow rectum leading to the anus (Plate V., fig. 4). The intestine is lined with a single layer of nucleated cells. Attached to this layer, and in some cases embedded in it at irregular intervals, are large cells filled with fine granular material. In some parts these large cells are grouped together two and three rows high. In other parts they are quite free (Plate V., figs. 5 and 6). The layer supporting the nucleated cells appears to be composed of fine muscle fibres. There is no chitinous inner lining as in *Lepeophtheirus.* Between the basement layer of the intestinal wall and the integument there is a network of muscles passing in various directions. This tissue represents the body-cavity and body-wall. The spaces between the muscles are filled with the red blood. The peristaltic movement of the intestine is similar to that observed in *Lepeophtheirus.*

In the cyclops stage the mouth leads into a short, narrow œsophagus (*œ*, Plate V., fig. 2), which passes into the comparatively wide stomach on its ventral aspect. The stomach is lageniform, with the narrow end pointing posteriorly. On the dorsal aspect, at the anterior end, it is produced into a short, blunt cæcum. The narrow end of the stomach connects with the intestine, a long straight narrow tube, greatly compressed over the region of the receptaculum seminis. The intestine terminates in a very short rectum leading to the anus. The cells both free and attached along the wall of the stomach and intestine are similar to those in the adult. Sometimes the stomach is filled with free cells, which are kept constantly travelling backward and forward by the movement of the intestine. At other times few free cells can be seen. No trace of blood between the alimentary canal and the integument, as found in the adult, has been observed in the young.

No trace of a digestive gland could be found in the adult. In the young it is probably represented by a series of groups of cells running along the lateral margins of th cephalo-thorax (Plate V., figs. 1 and 3, *l.v.*). A short duct could be traced leading from these groups into the stomach, just posterior to its junction with the œsophagus.

When the alimentary canal of a living parasite is opened, and the free cells are isolated and examined with a high power, they are found to be subspherical, granular, and of various shades of greenish yellow colour. Some of the cells exhibit faint amœboid movement. It is probable, therefore, that the digestion is intracellular.

The food of these parasites is undoubtedly blood which we find in the alimentary canal, but whether the absence of digestive glands in the adult accounts for its unchanged appearance has not been ascertained. In the young, where there is an apparent digestive gland, the contents of the alimentary canal are not red.

Circulation and Respiration.

There is no heart or vascular system, and in the adult no movement of fluids could be observed which would indicate a blood circulation. The animal is probably dependent upon the blood sucked from its host for the supply of oxygen necessary to maintain life. It is therefore possible that the early death after removal from the fish is due largely to the inability to take up oxygen from the water. The blood circulation could not be satisfactorily traced in the cyclops stage.

The Muscular System.

The muscular system in the cyclops stage, although not so highly developed, is practically similar to that of *Lepeophtheirus.* In the adult female it is simply a network between the integument and the alimentary canal forming a supporting medium for the latter.

The Nervous System.

In the cyclops stage the central nervous system is the same as in the adult *Lepeophtheirus.* The nerves supplying the various appendages have also the same origin and direction as described in that type. The nerves marked 4a, 4b, and 5a in Plate III., fig. 2, could not be traced.

The nerve supplying the antennules has a similar branching at its termination to that of *Lepeophtheirus*.

In the adult *Lernæa* no trace of a nervous system could be made out, and certainly if present at all it is very much reduced.

The Reproductive Organs.

The reproductive organs of *Lernæa*, like those of *Lepeophtheirus*, are bilaterally symmetrical. In the cyclops stage of the female (Plate V., fig. 1) the ovaries (*o.*) are pyriform organs lying on each side of the stomach. They are situated on the ventral surface near the posterior end of the cephalo-thorax. Each oviduct (*od.*) arises near the posterior end, and courses posteriorly as a narrow tube. When it enters the genital segment it expands rapidly, ending in a large sac, the receptaculum seminis (*s*), communicating with the vulva (*vu.*). The oviduct has no distinct loops, and no cement gland is found.

In the adult male (Plate IV., fig. 5) the testes (*t.*) occupy the same positions as the ovaries in the female. The vasa deferentia are straight, narrow tubes coursing posteriorly and terminating in the sacs of the spermatophores. A cement gland is present, as in *Lepeophtheirus*.

The ovary in the course of the metamorphosis undergoes great change of position. It is removed from the cephalo-thorax into the genital segment. It occupies a narrow region at the apex of the deep indentation (Plate V., figs. 4 and 5, *o.*). The two ovaries have also practically fused together, no separation is visible in transverse section. The united ovaries are produced into horn-like projections anteriorly and posteriorly (Plate V., fig. 5). The oviducts (*od.*) arise near the apex of the anterior horns, pass across the segment to its ventral surface, and then course along each side of the median line to the external openings. Each cement gland (Plate V., figs. 4, 5 and 7, *sg.*) is a long crystalline organ of nearly the same length and breadth as the oviduct, lying ventrally to it. The anterior part terminates at the base of the neck, in a blunt end. The posterior end communicates with the oviduct just inside the opening to the exterior.

The structure of the ovary of *Lernæa* differs considerably from that of *Lepeophtheirus*. In the cyclops stage it consists of a mass of minute nucleated cells. In the adult condition there are no tubules, and all the eggs are in close contact. The size of the eggs in the ovary of the adult varies from ·04 to ·08 mm. They are of the same structure and undergo the same changes in their passage along the oviduct as the eggs of *Lepeophtheirus* when they enter the thoracic ends of the oviducts. The ovisacs consist of long slender tubes very much twisted. (Plate IV., fig. 1, *os.*). When straightened out each tube is often found to attain the length of seven or eight inches. The eggs are arranged in a single column, and the period of incubation is of the same duration as in *Lepeophtheirus*. The death of the parent or detachment of the ovisacs has no effect on the vitality of the embryos.

Fertilisation of the female is effected during the fixed period of the cyclops stage. The spermatophores are attached to the female in a similar manner to that described for *Lepeophtheirus*. The contents pass into the receptacula seminis, and the empty sacs fall away. They are then replaced by others in succession, until the receptacula are filled. Each fully charged receptaculum represents the contents of four spermatophores (*rep.*, Plate IV., fig. 4). At first there is a distinct division between each lot, but this soon disappears, and the whole becomes one mass of spermatozoa. From a large number of females sectioned in various directions, the conclusion has been arrived at that the spermatozoa at once pass up the rudimentary oviduct to the ovary and fertilise the eggs. This probably accounts for the difference between the ovary of an adult *Lernæa* and *Lepeophtheirus*. No trace of a receptaculum seminis could be made out in the adult.

Life History.

The development of the embryo has not been worked out by the present author. An excellent work by D. Pedaschenko* contains a full description and figures of the developing embryo.

The young *Lernæa* hatches out as a nauplius, with three pairs of appendages, representing the rudimentary antennules, antennæ, and mandibles (Plate IV., fig. 2, nat. size, ·45 mm.). It then after a short pelagic life, settles on the apex of the gill filaments of the flounder, to which it adheres by a broad chitinous filament, and passes into a cyclopoid form (Plate IV., fig. 4). The young *Lernæa* are occasionally found on the gills of the plaice and lumpsucker. The parasite, by its attachment to the gill filament, produces a marked change in that organ. The whole of the apex assumes a tumid character, and the filamentous plates on both sides for some little distance disappear (Plate IV., figs. 8 and 9). While attached to the gills the various appendages develop. The male here reaches maturity (Plate IV., fig. 5), and undergoes no further change. In the female a considerable lengthening of the genital segment accompanies the appearance of the various appendages. Fertilisation next takes place; then the young female severs its connection

* Development of the embryo and metamorphoses of *Lernæa branchialis*. Trav. Soc. Imp. des Naturalistes de St. Petersbourg, vol. xxvi., livr. 4, No. 7, Sect. de Zool. et de Physiologie, 1898. (In Russian, with German resumé).

with the chitinous filament, and leads a pelagic life (Plate IV., fig. 4. Nat. size 2·3 mm.). This condition is frequently found in collections of plankton, and unless care be taken may readily be confused with immature stages of allied forms. I. C. Thompson, F.L.S.,† was the first to recognise certain copepods taken in collections of plankton from Liverpool Bay, &c., as the young of *Lernœa*, from Claus' figures. The presence of the males of *Lernœa* in plankton is to some extent accidental, as only the females lead a pelagic life. The males remain on the gills after the females have gone. The result of the examination of the contents of a fine filter, through which the waste water was passed from the tanks containing flounders in the Piel Hatchery, showed that females were always more numerous than males. The ratio, after a number of trials, was found to be one male to twenty-five females.

At the conclusion of the pelagic life the young *Lernœa* again fixes itself to the gills of a fish, and the retrogressive metamorphosis commences. The parasite buries its cephalo-thorax into the tissues. This region then develops into horns, which are situated one at each side and one dorsal. These pass out at right angles to the body into the tissues of the host. At first they are simple, but by gradual division in each horn they acquire the characters found in the adult (Plate V., fig. 8). The anterior part of the segment curves over, taking up the position shown on Plate V., fig. 4. The eyes, antennules, antennæ, mandibles and maxillæ disappear, leaving only the first maxillipedes, which are represented by small hooks in the adult. The free thoracic segments fuse, but the feet remain as in the cyclops stage. The genital segment elongates until fully fifteen times the original

† Revised Report on L.M.B.C. Copepoda. Trans. L'pool Biol. Soc. vol. vii., p. 212.

length. The abdomen only lengthens a very little. The elongation takes place during the development of the horns and before the eyes and the other organs disappear. This condition is shown on Plate IV., fig. 6; the nat. size is 11·4 mm. The next phase, represented on Plate IV., fig. 7. shows that the development of the horns, the disappearance of various appendages, and the great lengthening of the genital segment is followed by a looping of the posterior region of the latter. This loop gradually expands, and finally takes on the adult condition.

In the metamorphosis of the cephalo-thorax the ovaries are thrust into the genital segment, and take up a position on the dorsal aspect of the posterior region of that segment, in such a manner that the more anteriorly placed portion of the ovary in the adult is what was the posterior part in the cyclops stage (see Plate V., figs. 1 and 4).

The cyclops stage of *Lernœa* was first found *in situ* by Metzger,* who published a short note on the observations made and the conclusions arrived at early in 1868. Claus† later on in the same year, from specimens supplied by Metzger and fresh material, confirmed the observations of that Zoologist.

Concluding Remarks.

In the account set forth on the above pages, it will be seen that there are remarkable differences between the changes that take place in the life history of the two copepods before they reach maturity. In the one case (*Lepeophtheirus*) the life history exhibits a series of progressive developments. In the other (*Lernœa*), although

* Ueber das Männchen u. Weibchen der Gattung *Lernœa*, vor dem Eintritt der sog. rückschreitenden Metamorphose. Jany., 1868.

† Beobachtungen ueber *Lernœocera*, *Peniculus*, und *Lernœa*. 1868

for a time it advances, yet after a particular period has arrived the remainder of its development is retrogressive. The various appendages in each parasite are developed in the same order. In the one they become perfected when the creature is fully developed. In the other, long before the animal has reached maturity some have disappeared, the remainder continue in a rudimentary condition, and it is incapable of further movement. The internal organs of both copepods are developed in the same way. In one they continue advancing until perfected, and the animal is thus capable of living for considerable periods apart from its host. In the other, such organs as the digestive gland, the brain and nerves, and the blood system become rudimentary, if they do not altogether disappear. The ovary loses its original position and passes into the genital segment. The animal dies when removed from its host.

If only the adults were known, it would practically be impossible to recognise that such a form as *Lernæa* was in any way related to such a typical free-swimming Copepod as *Calanus*, and it would therefore still occupy an uncertain position. But when the whole life history of both copepods is known, tracing the connection becomes comparatively easy. Both originate from a free larval stage known as the nauplius, which has been regarded as the representative of a far back common ancestor. Both pass through a cyclops stage. The one ancestral cyclops form, we may suppose, by maintaining a free swimming life, gradually acquired more perfect appendages, and became at last the form now known as *Calanus*. The other cyclops form by adopting a sedentary life, and depending on other animals for its food, became semi-parasitic like many of the ascidian- and sponge-frequenting forms of copepoda. The transition from *Lichomolgus*-like copepods to such forms as *Bomolochus* and *Ergasilus* became simple. Further change in form and habit continued as the various appendages, through constant rest, degenerated. The animal became in consequence more and more dependent on its host for food. Such changes extending over a long period of time, have apparently resulted in such a form as *Lernæa*.

Some Zoologists divide the fish parasites into blood-suckers and mucus-eaters, on account of the apparent presence or absence of blood in the alimentary canal. It is doubtful if such a division is really satisfactory. The probability is that they are all blood-suckers in different degree, and that the presence of blood is only obvious because certain organs are absent. *Læmargus muricatus*, one of the *Caligidæ*, appears to make excavations into the skin of its host, *Orthagoriscus mola* (the short sun-fish). Several individuals are usually found in each excavation.* No obvious appearance of blood can be observed even in these parasites.

One or two parasites on a fish may not be hurtful, but when the numbers increase they probably have an irritating effect, and finally, when they remain in one position for some time, the skin and tissues become lacerated. Consequently even such external parasites as have been regarded as harmless mucus-eaters may really have an injurious effect upon the fish.

There is much opportunity for investigating the internal structures of the various families of fish parasites. The most of the literature hitherto published deals with the external characters only.

The specimens necessary for the work connected with this memoir have been almost entirely collected from fish caught in the vicinity of Piel. The author is indebted to Mr. R. Newsham, Jun., the Laboratory Assistant at Piel,

* A. Scott. Trans. Nat. Hist. Soc., Glasgow, vol. iii., part 3, p. 266. 1892.

for help in collecting. The important stage of *Lernæa*, shown on Plate IV., fig. 6, is drawn from a specimen sent by Mr. T. Scott, F.L.S., the author's father. It was found on the gills of a whiting caught in the Bay of Nigg, Aberdeen, in 1900, and was the only one met with in the course of these investigations.

Explanation of Plates.

Reference Letters.

a. antennule.
ai. antenna.
$a^{ii.}$ lateral frontal sucker.
an. anus.
b. median frontal sucker.
bls. blood space.
c. filament duct.
cg. filament gland.
cn. chitin.
D. dorsal.
d. opening of spermatophore.
e. eyes.
f. filament.
g. ganglia.
gl. gland.
i. intestine.
K^1 left anchor process.
K^2 median ,,
K^3 right ,,
L. left.
ld. duct of digestive gland.
lns. lens.
lv. digestive gland.
M. mouth.
m. mandible.
ml. muscle.
ml.a. antennule muscles.
ml.an. anal muscles.
ml.f. frontal muscles.
ml.i. intestine muscles.
ml.l. lateral muscles.
ml.m. mandible muscles.
ml.mxp. first maxillipede muscles.
ml.pt. posterior cephalic muscles.
ml.rt. rectum muscles.
ml.st. stomach muscles.
mx. first maxilla.
$mx^{i.}$ second ,,
mxp. first maxillipede.
$mxp^{i.}$ second ,,
n. nerves.
nc. nucleus.
o. ovary.
od. oviduct.
œ. œsophagus.
og. optic lobe.

om. muscles of the oviduct.
os. ovisacs.
ov. ova.
$p^{i.}$ first pair of feet.
$p^{ii.}$ second ,,
$p^{iii.}$ third ,,
$p^{iv.}$ fourth ,,
$p^{v.}$ fifth ,,
pg. pigment.
R. right.
r. rostrum.
rep. receptaculum seminis.
rt. rectum.
rtn. retina.
ry. fin ray.
S. spermatozoa.
sbg. subœsophageal ganglion.
sf. sternal fork.
sg. cement gland.
sp. spermatophore.
spg. supra-œsophageal ganglion.
st. stomach.
t. testis.
V. ventral.
va. vagina.
vd. vas deferens.
vu. vulva.
y. opening of digestive duct into the stomach.
z. pore canals.

Nos. 1 to 13 nerves, as follows:—

1. optic.
2. antennules.
3. antennæ.
4. mandibles.
4a. lateral frontal margins.
4b. first maxillæ.
5. second maxillæ.
5a. lateral cephalic muscles.
6. first maxillipedes.
7. second maxillipedes.
8. first feet.
8a. stomach muscles.
9. second feet.
9a. posterior cephalic muscles.
10. third feet.
11. fourth feet.
12. abdomen.
13. fifth feet.

Plate I.

Fig. 1. *Lepeophtheirus pectoralis*, mature female, dorsal view. × 17.

Fig. 2. *Lepeophtheirus pectoralis*, mature male, dorsal view. × 17.

Fig. 3. *Lepeophtheirus pectoralis*, nauplius stage, newly hatched. × 52.

Fig. 4. *Lepeophtheirus pectoralis,* "chalimus" stage. × 26.

Fig. 5. *Caligus rapax,* early "chalimus" stage attached to fin ray of young cod, the line $d' e'$ represents the surface of the skin. × 54·4.

Fig. 6. *Caligus rapax,* "chalimus" stage, previous to throwing off the filament attachment. On tail of young lumpsucker. × 15·24.

Fig. 7. *Caligus rapax,* mature, part of the frontal plate showing a lateral sucker. × 22.

Plate II.

Lepeophtheirus pectoralis.

Fig. 1. Female, ventral view, showing the various appendages and their muscles. × 17.

Fig. 2. Female, dorsal view, showing the chief muscles and blood currents. The arrows indicate the course of the blood. × 17.

Fig. 3. Female, ventral view, showing the digestive gland, its duct and alimentary canal. × 17.

Fig. 4. Female, ventral view, showing the reproductive organs. × 17.

Fig. 5. Male, ventral view, showing the reproductive organs. × 26.

Fig. 6. Genital segment and abdomen of an immature female, ventral view, showing vulva (*vu.*). × 40.

Fig. 7. Spermatophores detached from genital openings of a female. × 25.

Fig. 8. Mouth from the anterior base, with the mandibles inside, showing the muscles and ducts of digestive gland. × 25.

Fig. 9. Digestive gland. × 77.

Fig. 10. Longitudinal section of the ovary. × 50.

Fig. 11. Transverse section of pore-canal at the base of the mouth. × 350.

Plate III.

Lepeophtheirus pectoralis.

Fig. 1. Female, ventral view, showing the nervous system *in situ*. × 17.

Fig. 2. The nervous system from the ventral aspect. × 38.

Fig. 3. Female, nearly median longitudinal section. × 17.

Fig. 4. One of the antennules, showing the nerve endings. × 76.

Fig. 5. Median longitudinal section of the ganglia, showing the "pinhole" œsophagus passing through between the supra and sub-œsophageal parts. × 77.

Fig. 6. Transverse section in the region of the eyes. × 38.

Fig. 7. Transverse section in the region of the supra- and sub-œsophageal ganglia. × 35.

Fig. 8. Transverse section in the region of the second maxillipedes. × 30.

Fig. 9. Transverse section through the genital segment, female. × 30.

Fig. 10. Transverse section through the genital segment, male. × 38.

Fig. 11. Part of a transverse section of the intestine. × 76.

Fig. 12. Horizontal section of the dorsal aspect of the supra-œsophageal ganglion, showing the crossing of the fibres of the optic nerves. × 152.

Fig. 13. Transverse section of the eyes. × 152.

Plate IV.

Lernæa branchialis.

Fig. 1. Mature female, from the right side. The line $f' \; g'$ shows how much of the anterior portion is buried in the branchial arch. × 4·3.

Fig. 2. Nauplius stage, newly hatched. × 50·8.

Fig. 3. Very young female, unfertilised, dorsal view. From gills of flounder. × 51·5.

Fig. 4. Fertilised female, dorsal view. Just after leaving the gills of flounder. × 27·6.

Fig. 5. Mature male, dorsal view. From gills of flounder. × 28·5.

Fig. 6. Fertilised female, "Penella" stage, dorsal view. Just after settling on gills of *Gadus* (whiting). × 15·5.

Fig. 7. Later stage than Fig. 6, from the left side. The folding has just finished. Nat. size.

Fig. 8. Apex of gill filament of flounder, showing malformation caused by the young *Lernæa.* × 18·6.

Fig. 9. Apex of gill filament of flounder, normal. × 18·6.

Plate V.

Lernæa branchialis.

Fig. 1. Fertilised female, ventral view, showing the appendages, the reproductive organs, and nervous system. × 47·6.

Fig. 2. Nearly median longitudinal section of the same. × 47·6.

Fig. 3. Transverse section in the region of the eyes. × 80.

Fig. 4. Mature female, from the right side, showing the first maxillipede and the four pairs of feet, the alimentary canal and the reproductive

o Bank Shrimping Ground

	Dabs. Total Numbers.	Dabs. Average Numbers per haul.	Whiting. Total Numbers.	Whiting. Average Numbers per haul.
18	127	32	69	17
	3304	826	965	241
	2276	758	3850	1283
	2115	423	2480	496
	241	241	53	53
	536	268	130	65
	426	213	18	9
18	531	265	165	82
	746	186	266	66
	2084	417	1101	220
	2379	595	524	131
	2545	636	571	143
	2633	293	227	25
	983	327	2160	720
	10801	1800	7493	1249
	1283	321	4014	1003
	1410	470	1561	520
18	0	0	0	0
	306	102	237	79
	1977	247	683	85
	2765	691	302	75
	5117	1023	9500	1900
	1621	540	5272	1757
	705	705	1224	1224
	3003	1001	2434	811
	345	345	292	292
	193	193	71	71
18	546	273	258	129
	626	313	741	370
	498	249	294	147
	1963	654	361	120
	1169	584	3534	1767
	981	981	1433	1433
	150	150	298	298
	1534	511	800	266
189	96	96	215	215
	88	44	257	128
	287	287	150	150
	658	329	1186	593
	756	756	252	252
189	1628	407	1352	338
	1678	559	1967	656
	8374	1196	9677	1382
	1071	535	2676	1338
189	718	119	94	16
	3	3	71	71
	8340	556	17608	1174
	982	491	654	327
	829	207	933	233

TABLE I.—Abstract of the results of Hauls with a Shrimp Trawl made on the Burbo Bank Shrimping Ground (Area A) during the period 1893—1899.

DATE.	Number of Hauls.	Total Nos. of Fish.	Average Nos of Fish per haul.	SHRIMPS. Total Nos. of quarts.	SHRIMPS. Average Nos. of quarts per haul.	PLAICE. Total Numbers.	PLAICE. Average Numbers per haul.	SOLES. Total Numbers.	SOLES. Average Numbers per haul.	DABS. Total Numbers.	DABS. Average Numbers per haul.	WHITING. Total Numbers.	WHITING. Average Numbers per haul.
1893—May ...	4	1005	251	$16\frac{1}{4}$	4	742	185	28	7	127	32	69	17
June ...	4	5948	1489	38	$9\frac{1}{2}$	1868	467	48	12	3304	826	965	241
August ...	3	8165	2722	61	$20\frac{1}{3}$	1810	603	109	36	2276	758	3850	1283
September	5	19593	3919	78	15·6	14548	2910	173	35	2115	423	2480	496
October ...	1	662	662	0·125	0·125	280	280	2	2	241	241	53	53
November	2	866	433	2·25	1·125	170	85	2	1	536	268	130	65
December	2	621	310	10	5	162	81	0	0	426	213	18	9
1894—January ...	2	1235	617	14	7	492	246	15	7·5	531	265	165	82
February	4	1792	448	16	4	699	175	20	5	746	186	266	66
March ...	5	5237	1047	48	9·6	1474	295	301	60	2084	417	1101	220
April ...	4	3922	980	30·5	7·6	1067	267	83	21	2379	595	524	131
May ...	4	5376	1344	26·75	6·7	2010	502	82	20·5	2545	636	571	143
June ...	9	6599	733	76·5	8·5	2932	326	318	35	2633	293	227	25
July ...	3	3838	1279	24·5	8·1	461	153	69	23	983	327	2160	720
August ...	6	21913	3652	62·5	10·4	3329	555	95	16	10801	1800	7493	1249
September	4	8111	2028	133	33·2	2283	571	39	9	1283	321	4014	1003
October ...	3	3682	1227	130	43·3	680	226	28	9	1410	470	1561	520
1895—March ...	2	53	26	0·5	0·25	40	20	0	0	0	0	0	0
April ...	3	734	245	18	6	170	56	4	1·3	306	102	237	79
May ...	8	3671	459	102·5	13	571	71	158	20	1977	247	683	85
June ...	4	3575	894	50	12·5	272	68	29	7	2765	691	302	75
July ...	5	19245	3849	136	27	3104	621	129	26	5117	1023	9500	1900
August ...	3	8750	2916	22	7·3	982	327	63	21	1621	540	5272	1757
September	1	4404	4404	7	7	2315	2315	5	5	705	705	1224	1224
October ...	3	8897	2965	25·5	8·5	1747	582	0	0	3003	1001	2434	811
November	1	1000	1000	9	9	284	284	0	0	345	345	292	292
December	1	385	385	6	6	62	62	0	0	193	193	71	71
1896—March ...	2	1911	955	12	6	954	477	5	2·5	546	273	258	129
April ...	2	2819	1409	5	2·5	1258	629	13	6·5	626	313	741	370
May ...	2	1481	740	10·5	5·25	649	324	5	2·5	498	249	294	147
June ...	3	4199	1399	13	4·3	1703	568	29	10	1963	654	361	120
July ...	2	6996	3498	8·5	4·25	2219	1109	49	25	1169	584	3534	1767
August ...	1	2608	2608	0·75	0·75	206	206	1	1	981	981	1433	1433
September	1	723	723	8	8	120	120	57	57	150	150	298	298
October ...	3	2920	973	92	30·6	397	132	128	43	1534	511	800	266
1897—February	1	446	446	1·5	1·5	94	94	34	34	96	96	215	215
April ...	2	490	245	2·5	1·25	190	95	66	33	88	44	257	128
August ...	1	1913	1913	2·5	2·5	1278	1278	197	197	287	287	150	150
September	2	2591	1295	5·5	2·75	685	342	62	31	658	329	1186	593
October ...	1	1228	1228	7	7	111	111	58	58	756	756	252	252
1898—July ...	4	5464	1366	41	10·2	1175	294	1060	265	1628	407	1352	338
August ...	3	4226	1409	16	5·3	166	55	341	114	1678	559	1967	656
September	7	20330	2904	57·5	8·2	1316	188	979	140	8374	1196	9677	1382
October ...	2	4686	2343	7	3·5	625	312	254	127	1071	535	2676	1338
1899—June ...	6	1308	218	60	10	112	18	223	37	718	119	94	16
July ...	1	201	201	7	7	30	30	43	43	3	3	71	71
August ...	15	31718	2114	292	20	2951	197	2361	158	8340	556	17608	1174
September	2	2133	1066	39	19·5	190	95	209	104	982	491	654	327
October ...	4	1237	309	23	5·7	79	20	236	59	829	207	933	233

rse, Rock, Queen's and Crosby

	Dabs. Total number.	Dabs. Average No. per haul.	Whiting. Total number.	Whiting. Average No. per haul.	
A	196	39	385	77	
M	9	9	6	6	
A	0	0	6292	2097	
Se	20	20	28	28	
O	855	171	966	193	
N	454	227	158	79	
D	1136	284	76	19	
Ja	1280	116	214	19	
F	7	7	0	0	
M	161	161	0	0	
M	17	5	61	20	
Ju	10	10	5	5	
Ju	140	140	156	156	
A	58	58	10	10	
D	164	164	22	22	
Ja	427	213	28	14	
M	0	0	0	0	Flounders and Cod only.
A	238	119	102	51	
M	66	22	292	97	
Ju	3155	1577	17	8	
Se	67	67	135	135	
O	338	338	211	211	
N	2767	1383	389	389	
Ja	1331	665	28	14	
F	147	147	29	29	
Ju	1	1	9	9	
M	23	23	14	14	
A	14	14	0	0	
Ja	820	410	23	11	
Ju	40	20	19	9	
Se	100	100	220	220	
N	1106	553	143	71	
De	140	140	20	20	
Ju	18	18	1	1	
Au	2782	695	466	116	
Se	1636	234	733	105	
Oc	705	176	15	4	

Table II.—Abstract of the results of Hauls with a Shrimp Trawl made in the Horse, Rock, Queen's and Crosby Channels (Area B) during the period 1893—1899.

Date.	No. of Hauls.	Total No. of Fish.	Average No. of Fish per haul.	Shrimps. Total No. of quarts.	Shrimps. Average No. of quarts per haul.	Plaice. Total numbers.	Plaice. Average No. per haul.	Soles Total number.	Soles. Average No. per haul	Dabs. Total number.	Dabs. Average No. per haul.	Whiting. Total number.	Whiting. Average No. per haul.	
1893.														
April	5	1019	204	13	2·6	378	76	22	4·4	196	39	385	77	
May...............	1	312	312	0·5	0·5	283	283	14	14	9	9	6	6	
August	3	7065	2355	43	14	13	4	14	4	0	0	6292	2097	
September	1	425	425	7	7	321	321	29	29	20	20	28	28	
October	5	3739	748	36	7	1846	369	22	4	855	171	966	193	
November	2	1054	527	8	4	843	421	2	1	454	227	158	79	
December	4	2933	733	1·75	0·5	1591	398	0	0	1136	284	76	19	
1894.														
January	11	5310	483	45	4	3400	310	0	0	1280	116	214	19	
February	1	669	669	0·125	0·125	530	530	0	0	7	7	0	0	
March	1	647	647	0·125	0·125	284	284	0	0	161	161	0	0	
May...............	3	430	143	12	4	166	55	109	36	17	5	61	20	
June	1	257	257	4·25	4·25	212	212	15	15	10	10	5	5	
July...............	1	753	753	13	13	367	367	55	55	140	140	156	156	
August	1	132	132	6·5	6·5	61	61	3	3	58	58	10	10	
December	1	394	394	6	6	201	201	0	0	164	164	22	22	
1895.														
January	2	1141	570	1·5	0·75	328	164	0	0	427	213	28	14	
March	1	12	12	0	0	0	0	0	0	0	0	0	0	Flounders and Cod only.
April	2	758	379	15	7·5	62	31	0	0	238	119	102	51	
May...............	3	399	133	10·5	3·5	26	8	2	0·6	66	22	292	97	
June	2	3946	1973	12	6	674	337	87	43	3155	1577	17	8	
September	1	466	466	2	2	166	166	11	11	67	67	135	135	
October	1	666	666	22	22	52	52	0	0	338	338	211	211	
November	2	4591	2295	8	4	1135	567	0	0	2767	1383	389	389	
1896.														
January	2	3830	1915	1	0·5	2393	1196	0	0	1331	665	28	14	
February	1	591	591	0·5	0·5	365	365	0	0	147	147	29	29	
June	1	17	17	4	4	6	6	0	0	1	1	9	9	
1897.														
March............	1	213	213	1	1	129	129	34	34	23	23	14	14	
April	1	243	243	0·5	0·5	158	158	50	50	14	14	0	0	
1898.														
January	2	2749	1374	11	5·5	1772	886	99	50	820	410	23	11	
July...............	2	1344	672	8	4	933	466	352	176	40	20	19	9	
September	1	417	417	18	18	18	18	108	108	100	100	220	220	
November	2	2350	1175	60	30	410	205	628	314	1106	553	143	71	
December	1	724	724	16	16	174	174	240	240	140	140	20	20	
1899.														
June	1	167	167	2	2	62	62	95	95	18	18	1	1	
August	4	3851	963	106·5	26·6	413	103	84	21	2782	695	466	116	
September	7	2977	425	198	28	622	89	258	37	1636	234	733	105	
October	4	1100	275	202	50	266	66	44	11	705	176	15	4	

Table III.—Shewing the average monthly catches of Shrimps and Fish on the Burbo Bank Shrimping Ground (Area A).

Date.	No. of Hauls.	Total No. of Fish.	Average No. of Fish per haul.	Shrimps. Total No. of quarts.	Shrimps. Average No. of quarts per haul.	Plaice. Total No.	Plaice. Average No. per haul.	Soles. Total No.	Soles. Average No. per haul.	Dabs. Total No.	Dabs. Average No. per haul.	Whiting. Total No.	Whiting. Average No. per haul.
January	2	1235	617	14	7	492	246	15	7½	531	265	165	82
February ...	5	2238	447	17·5	3·5	793	158	54	11	842	168	481	96
March	9	7201	800	60·5	6·7	2468	274	306	34	2630	292	1359	151
April	11	7965	724	56	5	2685	244	166	15	3399	309	1759	160
May............	18	11533	641	156	8·7	3972	221	273	15	5147	286	1617	90
June	26	21629	832	237·5	9·2	6887	265	647	25	11383	438	1949	75
July............	15	35744	2383	217	14·4	6989	466	1350	90	8900	593	16617	1108
August	32	79293	2478	456·75	14·27	10722	335	3167	99	25984	812	37773	1180
September ...	22	57885	2631	328	14·9	21457	975	1524	69	14267	648	19533	888
October	17	23312	1371	284·6	16·7	3919	230	706	41	8844	520	8709	512
November ...	3	1866	622	11·25	3·7	454	151	2	0·6	881	294	422	141
December ...	3	1006	335	16	5·3	224	75	0	0	619	206	89	30

Table IV.—Shewing the average monthly catches of Shrimps and Fish in the Mersey Channels (Area B).

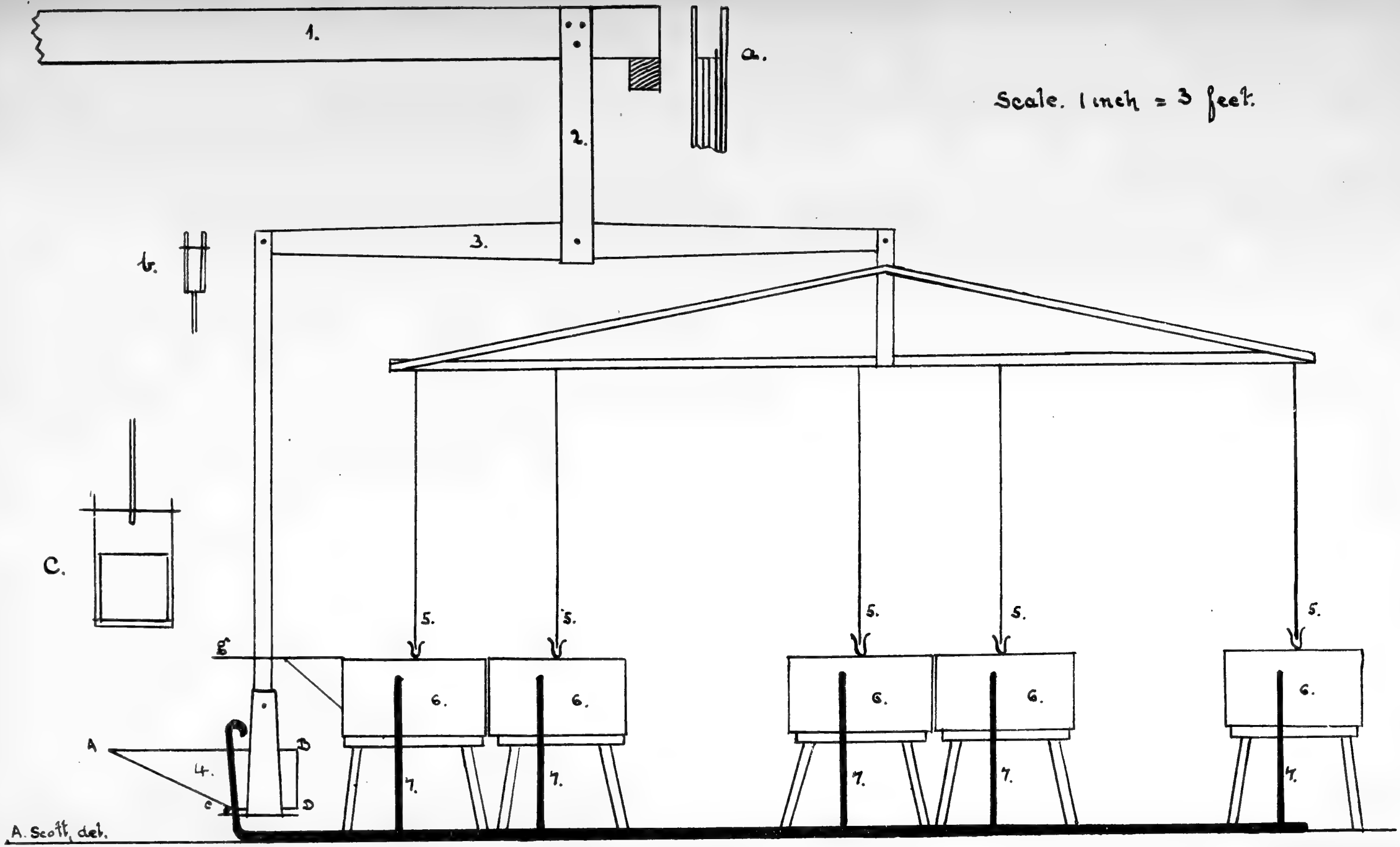
Date.	No. of Hauls.	Total No. of Fish.	Average No. of Fish per haul.	Shrimps. Total No. of quarts.	Shrimps. Average No. of quarts per haul.	Plaice. Total No.	Plaice. Average No. per haul.	Soles. Total No.	Soles. Average No. per haul.	Dabs. Total No.	Dabs. Average No. per haul.	Whiting. Total No.	Whiting. Average No. per haul.
January	17	13030	766	58·5	3·4	7893	464	99	6	3858	227	293	17
February ...	2	1260	630	0·625	0·312	895	447	0	0	154	77	29	14
March	3	872	291	1·125	0·375	413	138	34	11	184	61	14	5
April	8	2020	252	28·5	3·6	598	75	72	9	448	56	487	61
May............	7	1141	163	23	3·2	475	68	125	18	92	13	359	51
June	5	4387	877	22·25	4·45	954	191	197	39	3184	637	32	6
July............	3	2097	699	21	7	1300	433	407	136	180	60	175	58
August	8	11048	1381	156	19·5	487	61	101	14	2840	355	6768	846
September ...	10	4285	428	225	22·5	1127	113	406	41	1823	182	1116	112
October	10	5405	540	260	26	2164	216	66	7	1898	190	1192	119
November ...	6	7995	1332	76	13	2388	398	630	105	4327	721	690	115
December ...	6	4051	675	24	4	1966	328	240	40	1440	240	118	20

Table V.—Showing the ratio of Immature Fishes to Shrimps in the average monthly catches (Tables III. and IV.) taken on the Mersey Shrimping Grounds:—

Months. 1893-1899.	Area A.			Area B.		
	Soles. per Qt. Shrimps	Plaice. per Qt. Shrimps	Whiting. per Qt. Shrimps.	Soles. per Qt. Shrimps	Plaice. per Qt. Shrimps.	Whiting. per Qt. Shrimps.
January ...	1·1	35·1	11·8	1·7	134·9	5
February ...	3·1	45·3	27·5	0	1432	48·3
March	5·1	40·8	22·4	30·2	367	12·7
April	3·0	47·9	31·4	2·5	20·9	17·1
May	1·7	25·5	10·3	5·4	20·7	13
June	2·7	29	8·2	4·7	22·6	0·8
July	6·2	32·2	71·9	19·3	61·9	8·3
August	6·9	23·5	82·7	0·6	3·1	43·7
September ...	4·6	65·4	59·5	1·8	5	5
October	2·4	13·8	34·1	0·3	8·3	4·6
November ...	0·2	40·4	37·6	8·3	31·4	9
December ...	0	14	5	10·0	81·9	5

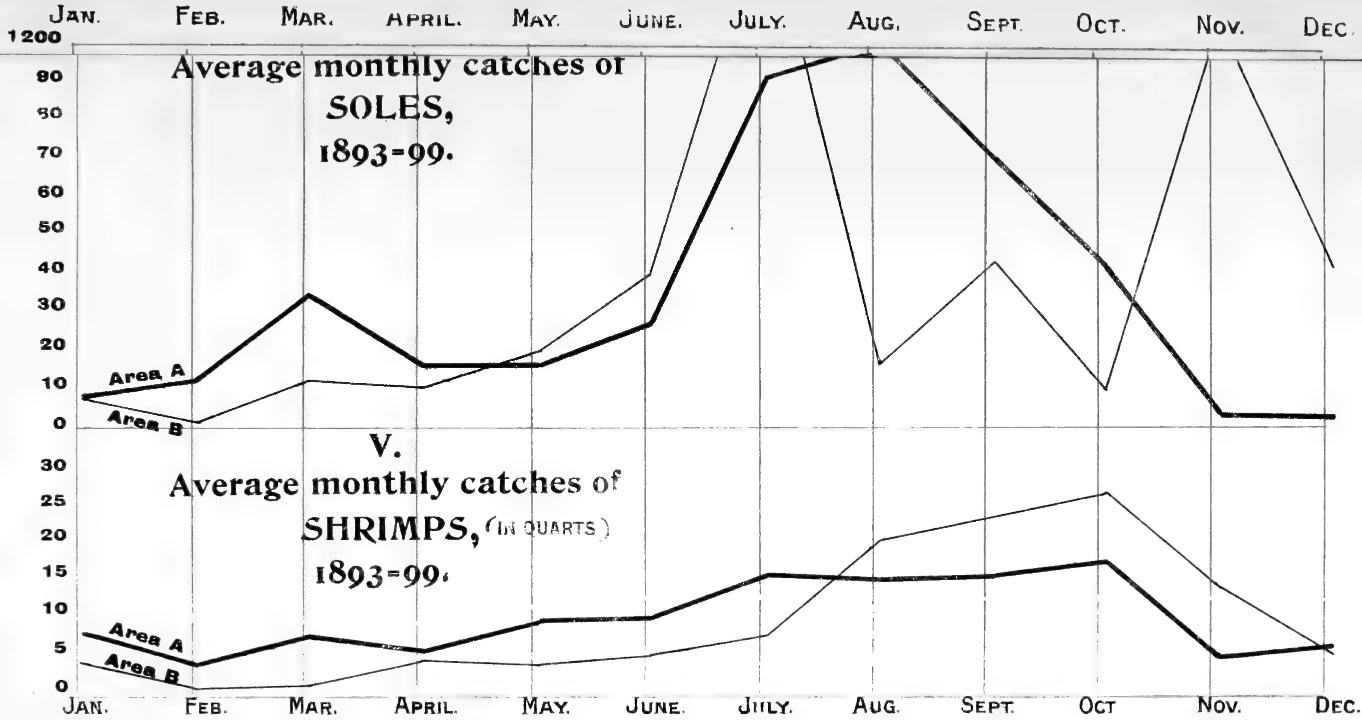
Table VI.—Shewing the Average Hauls made with a Shrimp Trawl during the 3rd quarters of the years 1893—1899 on the Burbo Bank Shrimping Ground (Area A):—

Date.	No. of hauls.	Shrimps. Total Quarts.	Shrimps. Av. Quarts.	Plaice. Total.	Plaice. Average.	Soles. Total.	Soles. Average.	Dabs. Total.	Dabs. Average.	Whiting. Total.	Whiting. Average.
1893—3rd quarter...	8	139	17	16358	2045	282	35	4391	549	6330	791
1894—3rd quarter...	13	220	17	6073	467	203	16	13067	1005	13667	1051
1895—3rd quarter...	9	165	18	6401	711	197	22	7443	827	15996	1777
1896—3rd quarter...	4	17·25	4·3	2545	636	107	27	2300	575	5265	1316
1897—3rd quarter...	3	8	2·6	1963	654	259	86	945	315	1336	445
1898—3rd quarter...	14	114·5	8	2657	190	2380	170	11680	834	12996	928
1899—3rd quarter...	18	338	19	3171	176	2613	145	9325	518	18333	1018



HATCHING APPARATUS.

PLATE B.



Miller, Litho. Preston

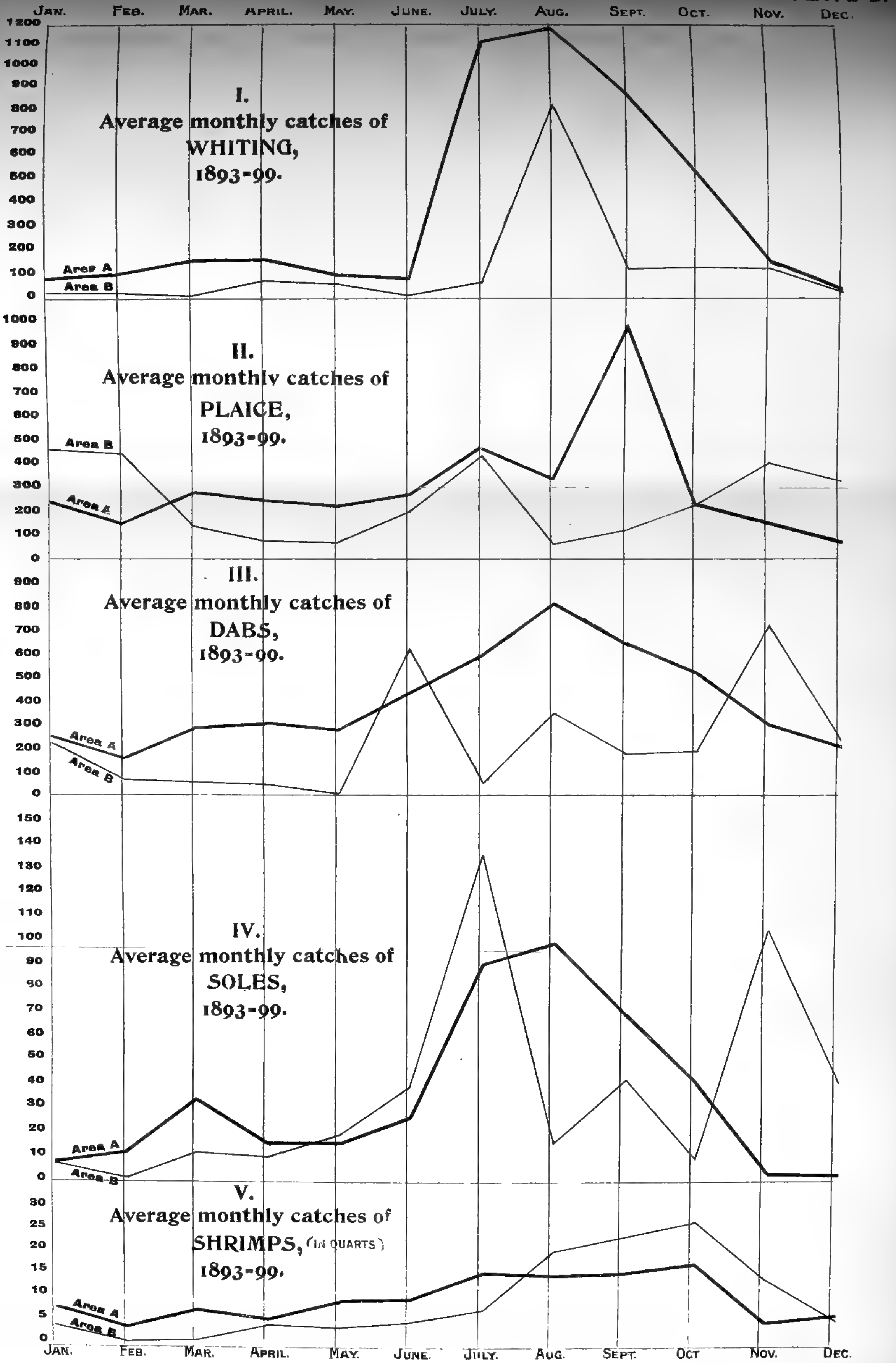
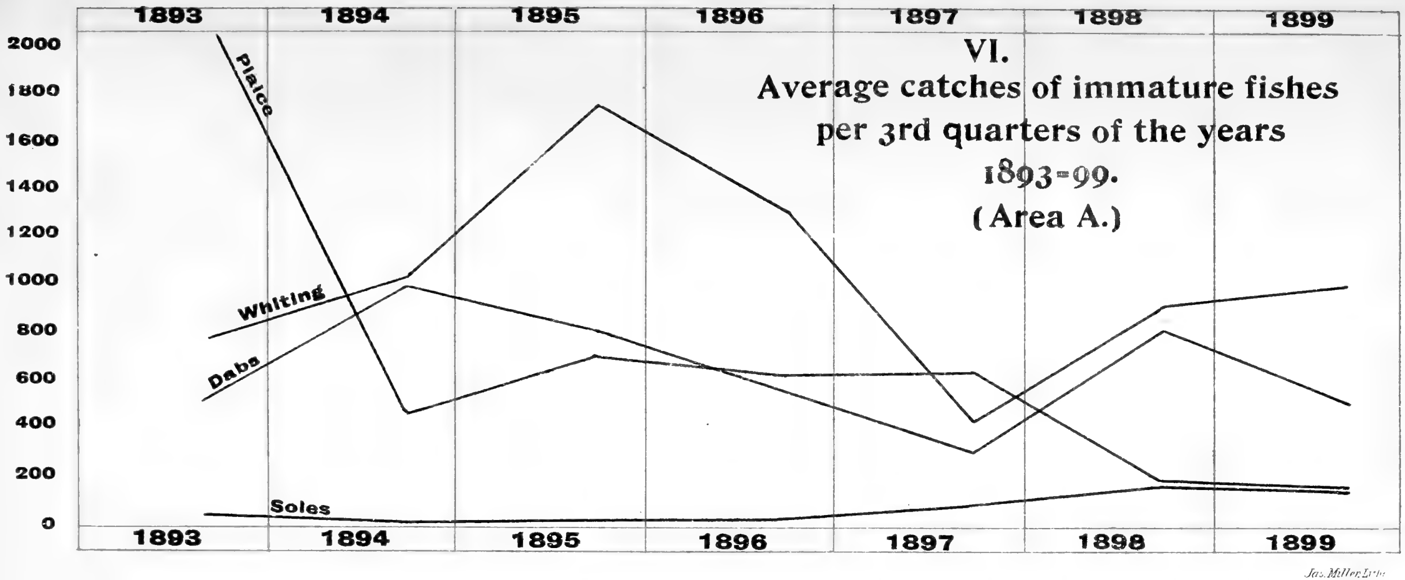

JAN.
FEB.
MAR.
APRIL.
MAY.
JUNE.
JULY.
AUG.
SEPT.
OCT.
NOV.
DEC.
I.
Average monthly catches of
WHITING,
1893-99.
Area A
Area B
II.
Average monthly catches of
PLAICE,
1893-99.
Area B
Area A
III.
Average monthly catches of
DABS,
1893-99.
Area A
Area B
IV.
Average monthly catches of
SOLES,
1893-99.
Area A
Area B
V.
Average monthly catches of
SHRIMPS, (IN QUARTS)
1893-99.
Area A
Area B

Plate C.


VI.
Average catches of immature fishes
per 3rd quarters of the years
1893-99.
(Area A.)
1893
1894
1895
1896
1897
1898
1899
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Plaice
Whiting
Dabs
Soles
Jas. Miller Lith.

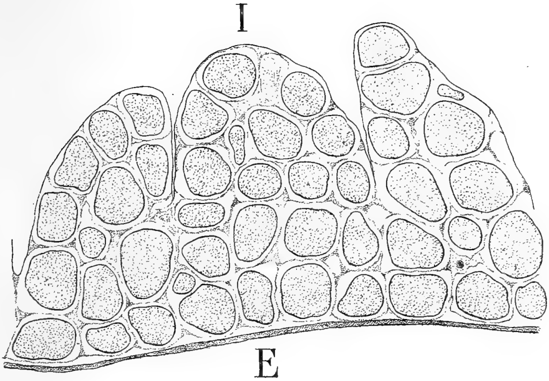


FIG. 2.

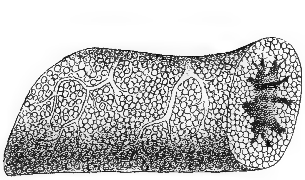


FIG. 1.

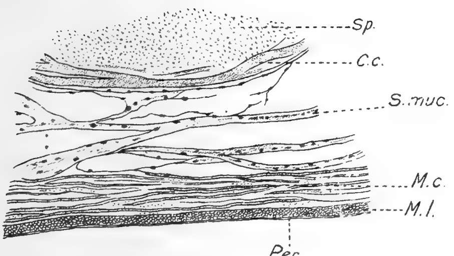


FIG. 3

FIG. 4.

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S. B. lith.

SPOROZOON FROM PLAICE.

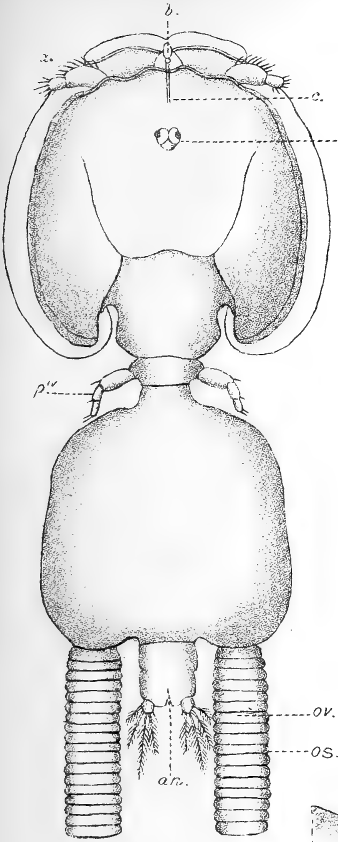


FIG. 1

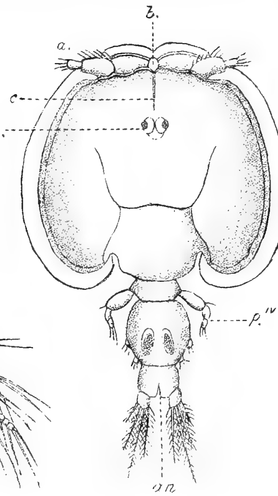


FIG. 2

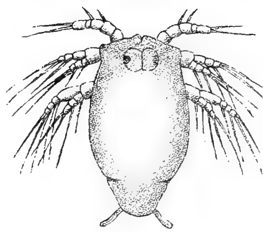


FIG. 3

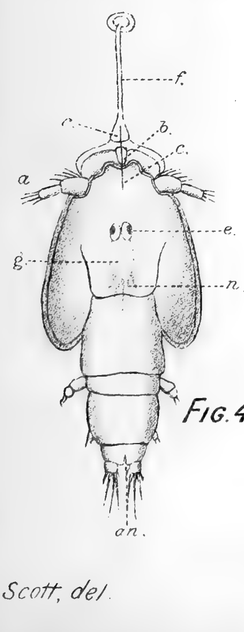


FIG. 4

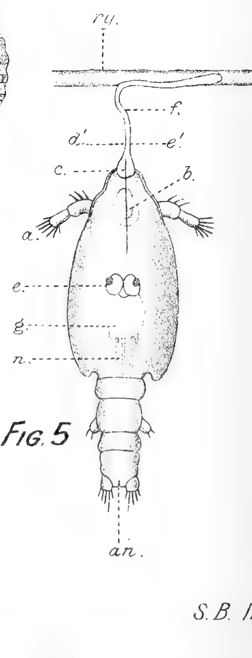


FIG. 5

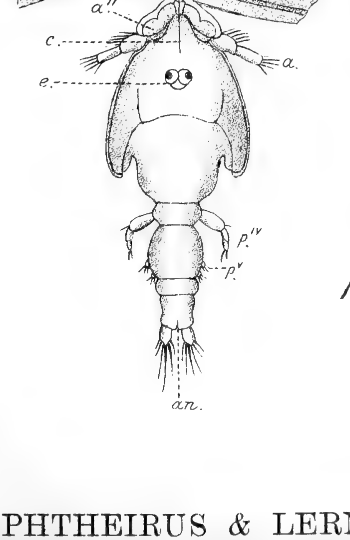


FIG. 6

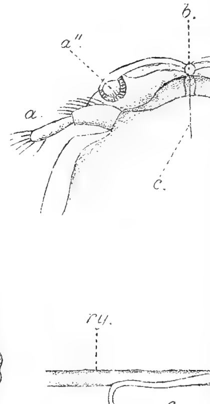
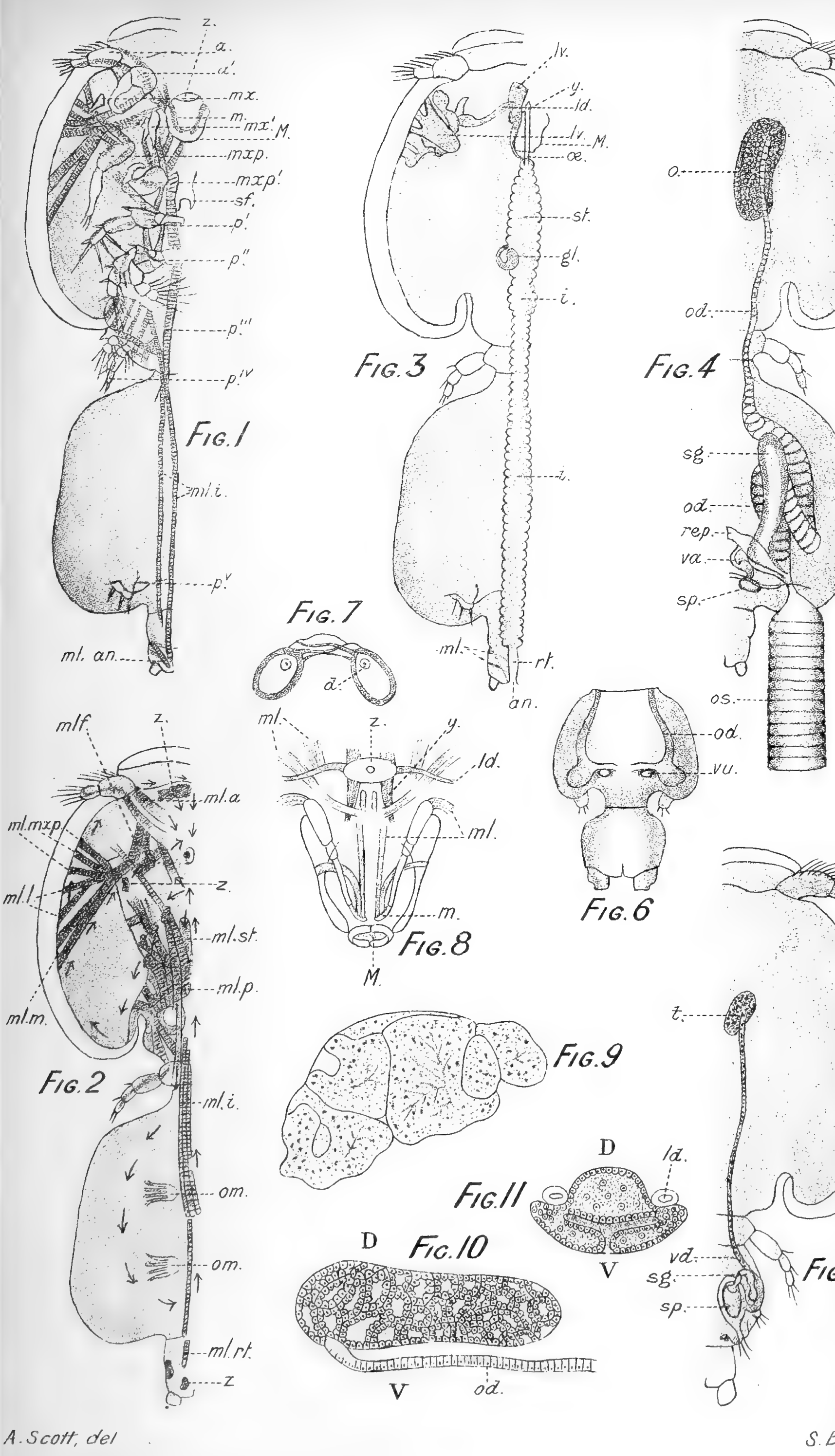


FIG. 7

A. Scott, del. S.B. lith.

LEPEOPHTHEIRUS & LERNÆA.



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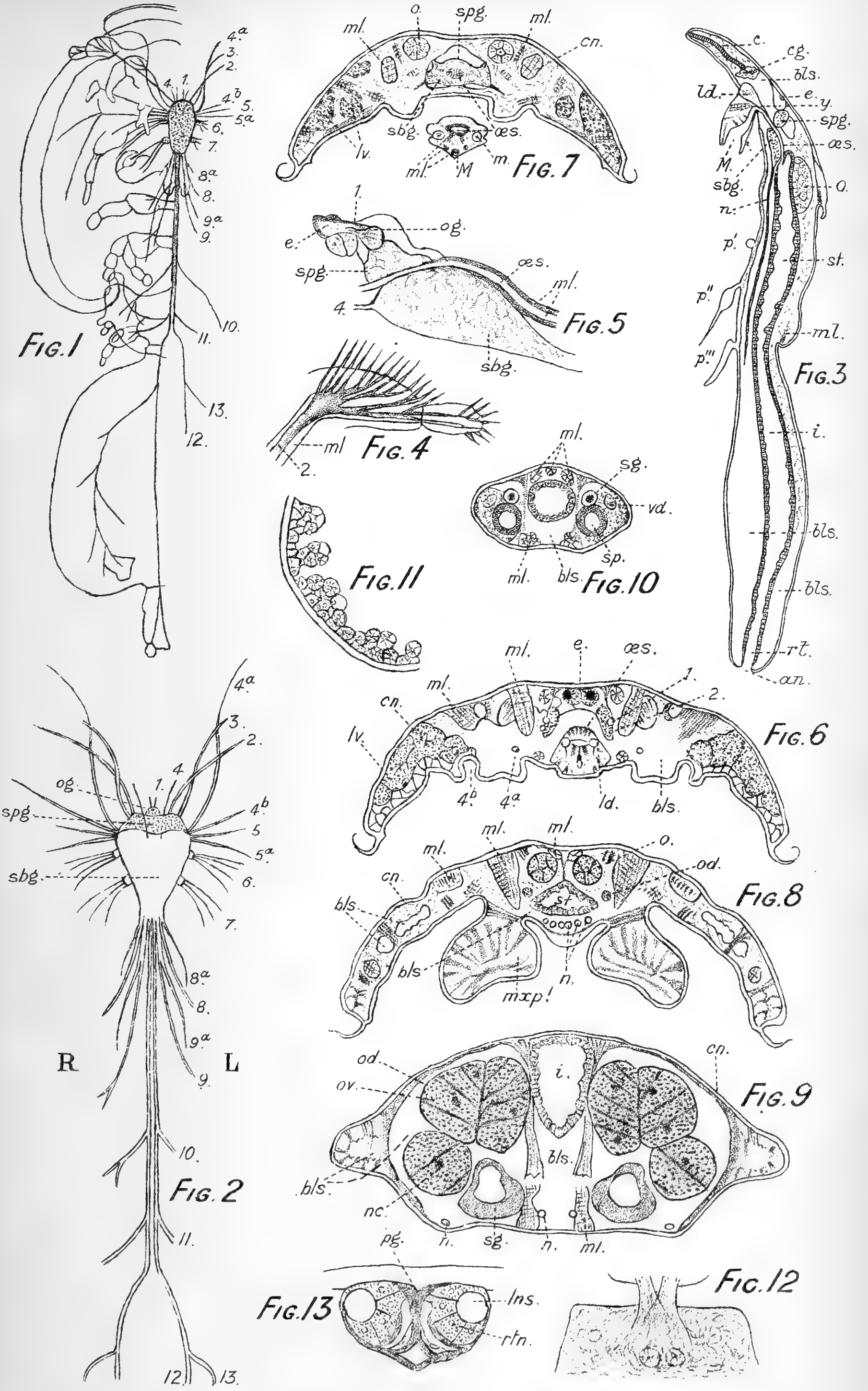

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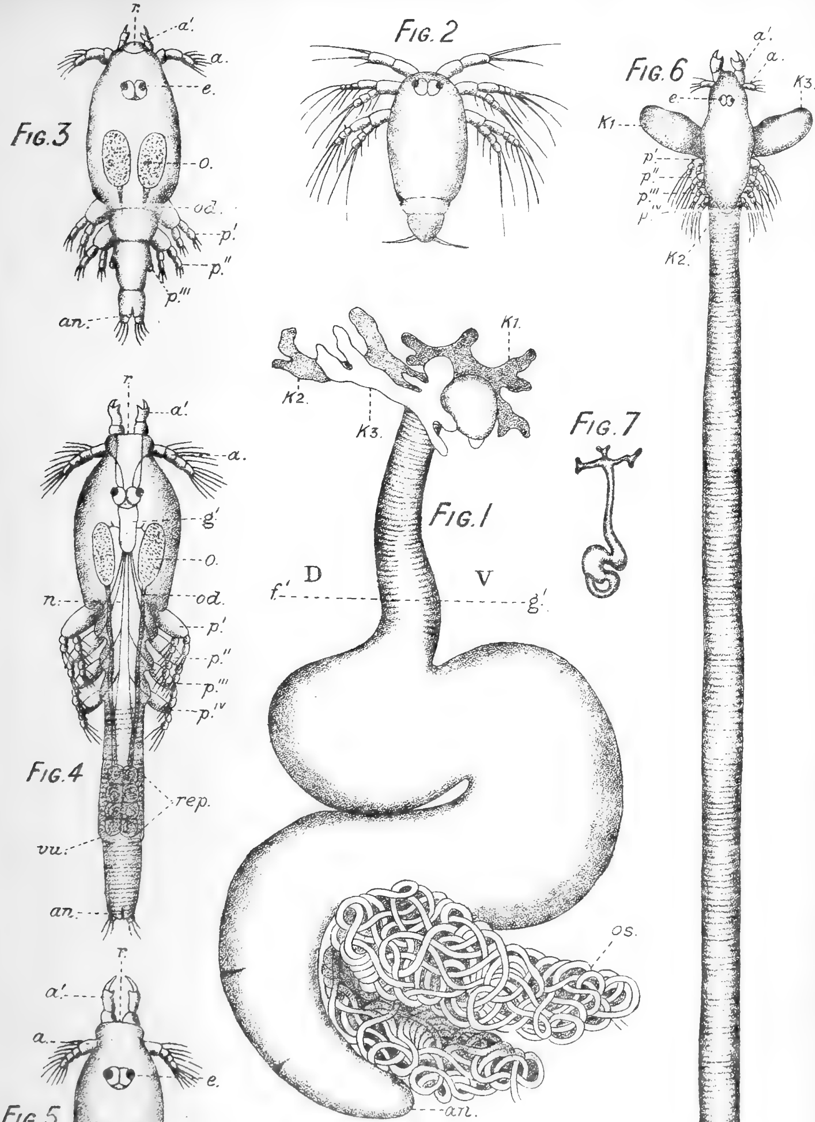

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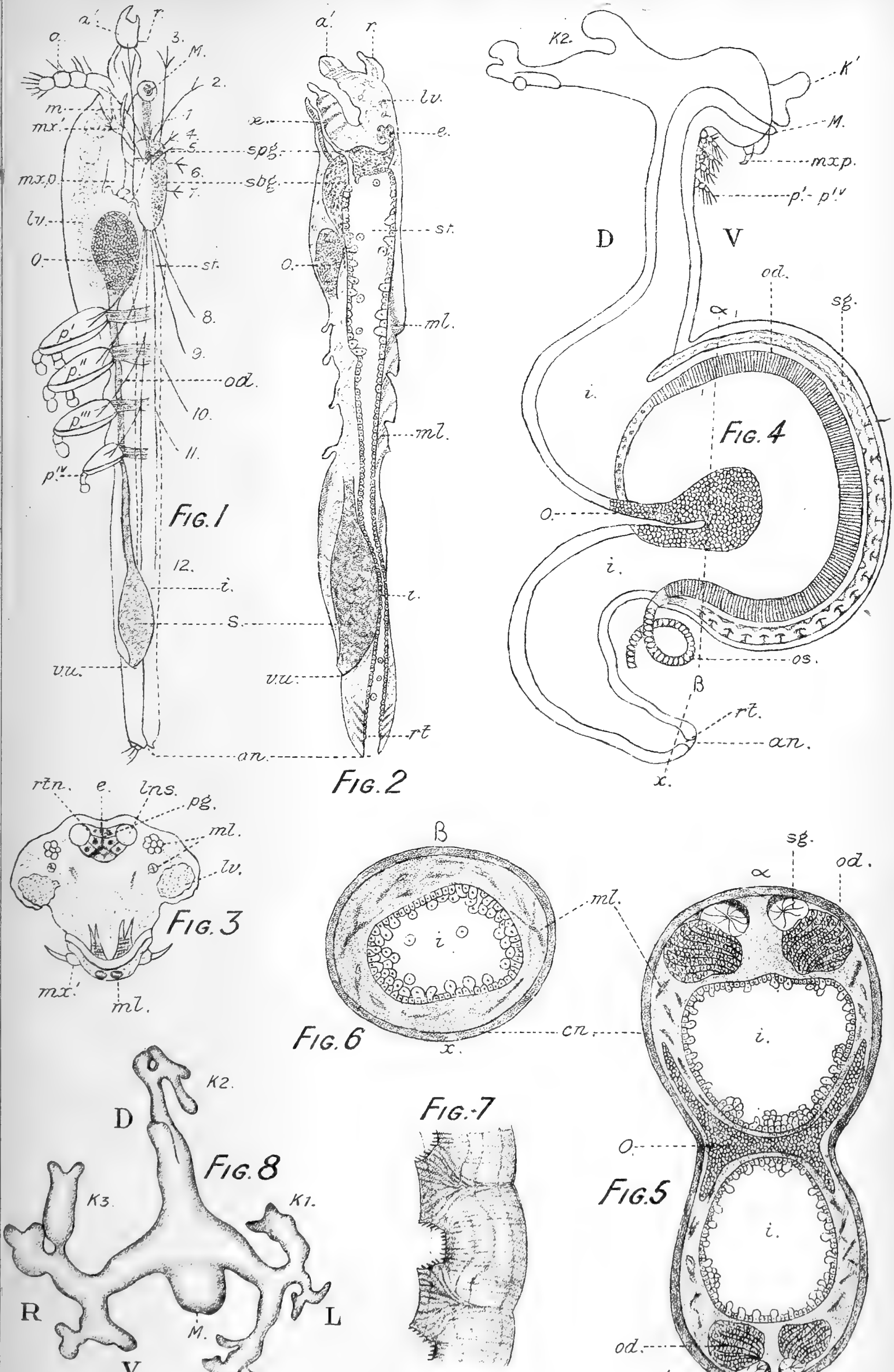


Scott, del S.B lith

LEPEOPHTHEIRUS & LERNÆA.

organs. The specimen was cleared in xylol, and the right anchor process removed. × 4.

Fig. 5. Transverse section through α β, (Fig. 4,) showing the muscular wall, the ovary, oviduct, cement gland, and intestine. × 9.

Fig. 6. Transverse section through x β, (Fig. 4,) just anterior to the rectum. × 20.

Fig. 7. Portion of the cement gland. × 20.

Fig. 8. Front view of the anchor processes of an adult female. × 4.

L.M.B.C. MEMOIRS.

No. VII. LINEUS.

BY

R. C. PUNNETT, B.A.

Introduction.

Since the time when it was first noticed by Pallas, in 1766, as "alia Lumbrici species marini tota atra," the Nemertean now known as *Lineus gesserensis* (which we choose as our type) has been the recipient of no less than 10 generic and 13 specific names associated together in various permutations and combinations. Our knowledge of the habits and anatomy of the worm are chiefly due to *M'Intosh, Barrois, Hubrecht, Oudemans, and Montgomery. Varying in size from about 6-20 cm., it is one of the commonest Nemerteans of our shores, occurring abundantly, and frequently in tangled masses, under stones between tidemarks and in the laminarian region.

* M'Intosh, W. C.—British Annelids, The Nemerteans, London, 1873.

Barrois, J.—Embryologie des Némertes, Annales des Sciénces Naturelles, Paris, 1877.

Hubrecht, A. A. W.—Contributions to the Embryology of the Nemertea, Quart. Journ. of Mic. Sc. 1886.

Oudemans, A. C.—The Circulatory and Nephridial apparatus of the Nemertea. Quart. Journ. Mic. Sc. Supplement, 1885.

Montgomery, T. H.—On the Connective Tissues and Body Cavities of the Nemerteans. Zoolog. Jahr. 1897.

,, Studies on the elements of the Central nervous system of the Heteronemertini. Journal of Morphology. 1897.

Its geographical range is extensive, since it occurs on the shores of both sides of the North Atlantic, extending from Greenland in the North to Madeira on the one side and Florida on the other. It also occurs, though not commonly, in the Mediterranean.

Two very distinct colour varieties are to be met with, viz., reddish brown and olive green—the latter being the more common. Specimens intermediate between these two are also frequent. The colour is more pronounced in front, and is darker on the dorsal surface than on the ventral. The snout and mouth are bordered by pale margins. On the head a reddish patch marks the position of the brain, and a bright red colouration is also found in the head slits which is said to be due to the presence of hæmoglobin. On the snout in front of the brain occur the deeply pigmented eyes usually varying from 3 to 6 in number on each side, though more may be present on one side than on the other.

Of the many openings on the body two may be readily seen—the proboscis pore at the tip of the head, and the mouth on the ventral surface just behind the brain. The anus is small and terminal. Of the other openings the lateral nephridial pores in the œsophageal region can only be made out in sections, whilst the numerous generative pores are at certain seasons visible under a lens as a row of white dots on either side in the intestinal region.

For what is known of the habits of the worm we are chiefly indebted to M'Intosh, who kept them in captivity. He states (in the work above cited) that "*Lineus gesserensis* "progresses in an easy, graceful manner, with slight "undulatory motions of the head, its body being marked "by successive contractile waves, which proceed from "before backwards. The specimens frequently herd "together in the water, which they are prone to leave, and "remain attached to the side of the glass a considerable "time. They are very easily kept in confinement for "years; but, as with many of their allies, great diminu- "tion of bulk occurs, from deprivation of the natural "supply of food. When recently captured specimens are "placed in a jar containing injured Annelida, numerous "fæcal masses, consisting of the bristles of *Nereis pelagica*, "and other annelids and digested matter, are found lying "on the bottom of the vessel, showing how greedily they "have fed; a fact, indeed, very easily ascertained by "actual observation. It is also frequently noticed that "specimens confined in vessels along with the deep green "*Eulalia viridis* assume a similar hue, probably from "feeding on the rejected débris of those animals, if not "upon the latter themselves. In their native haunts the "stones under which they lie are often placed on dark, "muddy, and highly odoriferous sand or gravel, and the "water cannot be otherwise than brackish at the estuary "of a river."

BODY WALL AND MUSCULAR SYSTEM.

The outside of the animal is completely covered with cilia, which are borne by long slender cells (Pl. II., fig. 3), widest externally where they carry the cilia, and narrowing to a very fine process which is somewhat branched, and is inserted into the basement membrane. They contain small elongated nuclei in the more external portion. The larger and more rounded nuclei found in the epidermis are for the most part connected with the large greenish unicellular gland cells occurring all over the skin. These last stain vividly with picric acid or with eosin, and it is probably their contents which give the skin its markedly acid reaction. These two forms of cell constitute the main mass of the epithelium, though it is possible that careful histological work may demonstrate the presence of ciliated cells modified to form sense cells somewhat resembling the rods of the vertebrate eye.

The basement membrane is structureless, and is composed of the intercellular substance around connective tissue cells. It takes a deep stain with hæmatoxylin or nigrosin, though it is apparently unaffected by the carmine dyes. Beneath the basement membrane is found a thin layer of fine circular muscle fibrils, and underneath those again a diffuse layer of small glands, each composed of several cells. The secretion of these cutis glands stains deeply with carmine or hæmatoxylin, and by it the minute ducts of the glands may be traced to their external openings. Mixed up with the cutis glands are numbers of connective tissue cells of a peculiar form containing pigment. These will be referred to later among the connective tissues. Around the cutis glands are also found the most external fibres of the external longitudinal muscle layer. The fibres are separated into a number of small bundles by the connective tissue, a structureless investment exhibiting the same staining affinities as the basement membrane, with which it is probably identical as regards composition.

Separating the outer longitudinal and the circular muscle layers (Pl. II., figs. 1 and 2, Pl. III., fig. 8) is a tunic of nervous tissue, consisting of fibrils given off from the lateral nerve cords, which also lie between the same two muscle layers. The circular muscle layer is on the whole not so thick as the outer longitudinal layer, and of about the same thickness as the inner longitudinal layer which it immediately invests. Towards the posterior portion of the body the outer longitudinal muscle layer becomes greatly diminished, whilst the internal longitudinal layer here surpasses the circular layer in thickness.

A thin layer of dorso-ventral muscles (Pl. III., figs. 6 and 8) is found running along each side of an intestinal diverticulum. In some Lineidæ a horizontal muscle layer runs between the proboscis sheath and œsophagus in the mouth region, but this layer does not occur in the present species. The muscle fibres in the head are continuous with the outer longitudinal layer. The inner longitudinal and circular layers of the trunk are not continued anteriorly beyond the brain. In the head, however, are developed an inner layer of longitudinal and an outer layer of circular fibres round the rhynchodæum and cephalic blood lacunæ (Pl. I., fig. 2).

PROBOSCIS AND PROBOSCIS SHEATH.

The remaining portion of the muscular system is that in connection with the proboscis and its sheath. These two structures commence at the anterior level of the brain, and their relations to one another and to the rhynchodæum may best be gathered from a reference to Pl. II., fig. 7. The proboscis sheath consists of a layer of longitudinal muscle fibres, surrounded externally by a layer of circular ones, and internally invested by the flattened epithelium of its contained cavity, the rhynchocœlom. In its retracted state the proboscis lies in the last-named cavity, and its outer surface is covered by the rhynchocœlomic epithelium.

The internal surface of the proboscis (*i.e.*, in the retracted state) is lined by the high glandular proboscidial epithelium, which is of ectodermal origin, and is continuous with the epithelium lining the rhynchodæum. In other words, the cavities of the retracted proboscis and the rhynchodæum are one and the same, whilst that of the rhynchocœlom is entirely closed and separated from the rhynchodæum by the attachment of the proboscis. When, as sometimes happens, the proboscis is violently extruded and broken off at its attachment the rhynchocœlom and rhynchodæum form a continuous cavity until the proboscis is regenerated. The rhynchocœlom contains a colourless corpusculated fluid.

At its commencement between the rhynchocœlom and rhynchodæum the proboscis consists of a layer of longitudinal muscle fibres covered externally by rhynchocœlomic and internally by proboscidial epithelium (Pl. I., fig. 4, *p.*). Just beneath the last layer are the two proboscidial nerves. Further back the proboscis becomes considerably thicker, and a layer of circular muscles makes its appearance between the longitudinal muscles and the proboscidial epithelium. From this circular layer at two opposite poles, as seen in transverse section, fibres pass through the longitudinal layer to the basement membrane just beneath the rhynchocœlomic epithelium, crossing one another in two directions (Pl. II., fig. 6, *mcr.*). In this way are formed the so-called muscle crosses characteristic of the Lineid proboscis. The crossing is more apparent on one side than on the other. In this region also the proboscidial epithelium is thrown up into papillæ, and is highly glandular, whilst just beneath it there is a complete investing nervous layer which has been formed from the two proboscidial nerves. Still further back (Pl. II., fig. 5), the nervous layer and the circular muscles disappear, so that, except for the absence of the two proboscidial nerves, the appearance of a section taken in this region is somewhat similar to that of one taken near the attachment of the organ (*cf.*, Pl. I., fig. 6).

The proboscis is attached by its hinder end to the dorsal wall of the proboscis sheath about one-third of the length of the animal from the anterior end. This is effected by the longitudinal muscles of the proboscis being continued beyond the proboscidial epithelium and its contained cavity, and fusing with the muscles of the proboscis sheath. The muscular slip so formed has been termed the retractor muscle of the proboscis, though it is doubtful whether it exercises the function which its name implies. Not only does it appear too slender to exert the necessary force, but the distance between its point of attachment to the proboscis sheath and the proboscis pore is considerably less than the length of the proboscis. Such considerations, coupled with the fact that in some nearly allied species no retractor muscle is present, would seem to indicate that, whilst expulsion is due to pressure exerted on the rhynchocœlomic fluid by the circular muscles of the proboscis sheath or of the body wall, retraction is probably accomplished by a peristaltic movement of the proboscis itself. Such a form of movement may be observed in the isolated proboscis, and once gave rise to the view that these worms were viviparous—the extruded and broken-off organ being mistaken for a young worm just born.

THE ALIMENTARY CANAL.

The mouth in the living and active animal is an elongated slit on the ventral surface just behind the brain. When widely open under the influence of a narcotic it becomes circular in outline, and surrounded by a prominent and somewhat rugose lip. In life apparently one of its functions is to act as a sucker, since, when the animal is forcibly removed from the surface on which it rests by a current of water from a pipette, the mouth area retains its attachment more vigorously than the rest of the body.

The œsophagus, into which the mouth leads, is thrown into a number of longitudinal furrows, which largely increase its surface (Pl. II., figs. 1 and 2). It has been suggested that this arrangement may subserve the purpose of respiration, and the vascular network which surrounds this region of the alimentary canal (Pl. II., fig. 2, *oesl.*), lends some support to such a view.

Histologically the œsophagus, like the rest of the alimentary tract, is lined by ciliated epithelium. Squeezed in among the ciliated cells (Pl. IV., fig. 3) is a number of large unicellular gland cells, among which two, or possibly three, types may be distinguished. After staining with borax carmine, followed by picro-nigrosin, many of these gland cells (Pl. IV., fig. 3, *β*) take a yellow stain. They appear to be full of large coarse granules. Others similarly granulated, though much less numerous, shew an intense crimson colouration (Pl. IV., fig. 3, *γ*). Except for the difference in staining reaction, these two types are indistinguishable. The greater number of the gland cells, however, present a different appearance. Their contents consist of a coarse spongy network, which presents a slaty-purple hue (Pl. IV., fig. 3, *a*). Whether these various types are in reality distinct, or whether they represent different stages in a single type, is a question which must be left for future histological investigation to decide.

Besides being found between the ciliated cells, these unicellular gland cells also occur massed beneath the ridges of the œsophageal epithelium. It seems feasible that these large glandular œsophageal cells supply the active juices of digestion, whilst the intestinal region is more concerned with absorption. The more granular of them bear a close resemblance to the large unicellular glands of the integument which, as has already been seen, are probably concerned with the markedly acid skin reaction. Such a fact lends some support to the view that the œsophagus is derived from the ectoderm, and, should future investigations prove such to be the case, the Nemerteans would present the interesting feature of possessing an endoderm which probably does not contribute to the digestive juices, but is only concerned with absorption. But in the absence of decisive embryological data, and of the histological appearance of the various parts of the lining of the alimentary canal after injection of various substances, nutritious or otherwise, the question must be left open.

The œsophagus is constricted at its posterior end, and behind this constriction starts the intestine, with its lateral pouches, where the character of the lining of the alimentary canal becomes entirely changed. The intestinal cells are large, though long and narrow (Pl. III., fig. 2). Each contains a somewhat elongated nucleus near its base, whilst between it and the ciliated surface are a number of small round bodies which shew neither nucleus nor any definite structure. These little bodies have been considered to be stored food material absorbed in this region, and in some Nemerteans several types have been distinguished.

The region of the regularly arranged intestinal diverticula (Pl. III., figs. 6, and 7, *i.d.*) continues almost to the anus where the alimentary canal opens to the exterior by a very short rectum. It is worthy of note that traces of food are rarely found in the digestive canal of a Nemertean. Yet various anecdotes illustrating their voracity have been given, among which may be mentioned an observation of *Riches, who, writing about *Micrura purpurea*, states that " A specimen of about 3 or 4 cm. was placed in a dish with

* Riches, T. H. A list of the Nemertines of Plymouth Sound. Journ. Marine Biol. Assoc. Vol. III.

"a *Eunemertes neesi* of quite 20 cm. length. Some little "time after I was astonished to find the *Micrura* busily "engaged in swallowing the *Eunemertes.* The posterior "one-fifth of the latter had already disappeared into the "mouth of the former when I noticed them, and still the "assailant was struggling to gulp down more of its prey. "In the meantime the victim glided round the dish, "apparently not suffering the slightest inconvenience "from the attack upon its posterior extremity. "Ultimately both attacker and attacked became quiescent, "the former having become more than twice its previous "girth. The portion of the *Eunemertes* in the gut of the "*Micrura* still remained in continuity with the rest of "the body, though apparently undergoing digestion." Possibly the food is digested and absorbed and the excreta expelled with a rapidity which precludes its presence within the alimentary canal for any length of time.

THE VASCULAR SYSTEM.

According to the histological structure of the walls, the vascular spaces in *Lineus* are spoken of partly as lacunæ and partly as vessels. The lacunæ are found in the head and in the œsophageal region. They are surrounded by connective tissue, and their only wall consists of a delicate membrane on which occur small oval nuclei at intervals. The vessels, which occur only in the intestinal region, possess a rather more elaborate structure. They are lined by an endothelium (Pl. IV., fig. 2), closely packed with spherical nuclei, and in which cell outlines are not readily to be distinguished. This endothelium rests upon a well-marked structureless basement membrane, but no circular muscle fibres are present. External to the basement membrane is a layer of large parenchyma cells, highly vacuolated and with definite cell outlines.

In the precerebral region the vascular system consists of two lacunæ (Pl. I., fig. 2), which join at the tip of the head over the rhynchodæum. These two cephalic lacunæ, together with the proboscis sheath, are surrounded by the nervous ring. About the level of the ventral commissure of the brain they unite in the mid-ventral line below the proboscis sheath, and from the commissure so formed is given off the median dorsal vessel (or more properly lacuna). Further back the lateral lacunæ form a second ventral communication, whence spring the two small buccal vessels which join the vascular network in the œsophageal region. Soon after this the lateral lacunæ widen out greatly, and surround the hinder portion of the cerebral organs. Just behind the mouth there is a continuous network of œsophageal lacunæ surrounding the ventral surface of the œsophagus (Pl. II., fig. 2), though the lateral lacunæ can still be recognised as the largest and most dorsal of the spaces seen in transverse section. They are in close proximity to the proboscis sheath, and the nephridial tubules come into contact with them (Pl. II., fig. 2, *ext.*).

The median dorsal vessel pierces the wall of the proboscis sheath directly after its formation at the level of the brain, and lies in the median ventral line. Directly over it the rhynchocœlomic epithelium, which alone separates the vessel from this cavity, assumes a columnar appearance. The œsophageal lacunar network extends nearly to the end of the œsophageal region. It then terminates, and the lateral lacunæ become much smaller and transformed into the lateral vessels which at first lie just above the level of the lateral nerves, but soon take up a position ventral to the intestine, and not far removed from the mid-ventral line. At about the same level the median dorsal vessel leaves the proboscis sheath, and becoming a true vessel, runs for the rest of its extent between the proboscis sheath and the intestine. In the intestinal region the lateral and median dorsal vessels communicate by a series of commissures (Pl. IV., fig. 1, *cbv*) passing round the diverticula, and which are of lacunar nature, being devoid of the investing layer of parenchymatous cells. As the lateral vessels do not communicate ventrally, the last commissure of the vascular system lies dorsal to the alimentary canal.

The blood is colourless, and contains some corpuscles. In some Nemerteans it is red from the presence of hæmoglobin. As to its course, it has been stated to flow backwards in the median dorsal and forwards in the lateral vessels. It is possible, however, that, in the absence of contractile fibres in the vascular system, there is no definite circulation, but that the blood is intermittently kept in motion by contraction of the muscles of the body wall. To what extent the vascular fluid acts as a respiratory medium is open to question. The vascular network round the œsophagus of many Nemerteans and the occasional presence of hæmoglobin suggest that it may have such a function, but against this must be set the fact that the œsophageal lacunæ are not present in some groups, and also that the presence of hæmoglobin is of rare occurrence. A more likely view is that respiration is mainly, if not entirely, carried out by the integument of the smaller forms; and this may also be the case even in the larger ones, since the body is usually capable of extreme attenuation.

EXCRETORY SYSTEM.

The so-called excretory or nephridial system in *Lineus gesserensis* consists of a number of small tubules lying in close proximity to the lateral lacunæ in the œsophageal region (Pl. II., fig. 2), and communicating with the exterior by a number of fine ducts which pierce the body wall and open laterally above the level of the lateral nerves. The number of ducts varies both in different specimens and on the two sides of the same specimen (Pl. IV., fig. 1, *exd.*). There are usually from 6 to 12 on each side. It often happens that some of the ducts are incomplete, the portion which would pierce the circular muscle layer being missing, though whether this is due to such ducts being new formations in course of inward growth from the ectoderm, or whether they are commencing to atrophy is an undecided point.

It has been stated that the number of ducts increases with the growth of the animal, from which it would appear that such incomplete ducts belong to the former of the above categories. On the other hand, the writer's own experience is that a large specimen may have but half as many ducts as one considerably smaller, though in such a case certain of the ducts in the large specimen may possess a very much wider lumen than the rest. Consequently it is quite likely that there is a period in which the number of ducts increases, and then later a period in which certain of the ducts enlarge, with the result that others atrophy through disuse. But the question is one that requires more fully working out.

The excretory tubules commence not far behind the mouth, and extend almost to the end of the œsophageal region (Pl. IV., fig. 1). Directly they cease the lateral blood lacunæ become the lateral vessels and the median dorsal vessel leaves the proboscis sheath. Histologically the tubules consist of what would probably be styled cubical epithelium, were it possible to distinguish the cell outlines. Its protoplasm, which stains readily, is somewhat granular and contains spherical nuclei (Pl. III., fig. 5). It is sparingly provided with long cilia. Near the blind end of a tubule these cilia are often more abundant, and are directed away from the blind end (Pl. III., fig. 5). No flame cells, however, have been detected in this species.

The excretory system lies almost wholly above the level of the lateral nerve cords, never extending into the lacunar network ventrally. Though it is in close contact with the œsophageal lacunæ, there is no communication between the vascular and excretory systems. Although certain observers claim to have demonstrated such a communication for certain of the more primitive forms, such as *Carinella* and *Carinoma*, it is exceedingly doubtful whether it exists. Concerning the nature of the fluid contained in the excretory system no observations have been made.

NERVOUS SYSTEM.

The nervous system consists essentially of two longitudinal cords extending throughout almost the entire length of the body and dilating anteriorly into the brain. Posteriorly they unite by a fine commissure ventral to the rectum. For their whole course they lie immediately outside the circular muscle layer, and are conspicuous objects in a transverse section of the worm (Pl. III., fig. 8, *ss.*). Viewed thus they are seen to be composed of an inner granular-looking portion of a more or less circular outline, surrounded by a layer of ganglion cells. The latter are not present on the side next to the circular muscles, and are very scarce externally. The fibrous core is bounded by a thin connective tissue layer, the inner neurilemma, separating it from the ganglion cells. Outside the ganglion cells is another connective tissue layer, which has been termed the outer neurilemma. The inner neurilemma is broken at intervals by small bundles of axis cylinders from the ganglion cells, which can be traced into the fibrous core. Scattered nuclei are found inside the fibrous core, for the most part just inside the inner neurilemma, though a few may be seen about the centre of it. These are the nuclei of the neuroglial cells, whose branched processes form the supporting groundwork of the nervous system. The fibrous core itself is composed of:—

(1) Fibres of the neuroglial cells, which stain with many reagents (*e.g.*, eosin), and compose the bulk of the core.

(2) Nerve tubules, consisting of homogeneous axis cylinders which are usually unstained by reagents, and probably in life consist of a semi-fluid substance bounded by a fine spongio-plasmic sheath. These tubules are very small, and are for the most part scattered about inside the fibrous core, though near the centre a large space is seen, more or less circular in outline in transverse section, which is found throughout the whole length of the core, and probably represents a bundle of nerve tubules.

(3) Irregular spaces containing fluid.*

Returning now to the general arrangement of the nervous system, it has already been mentioned that the lateral nerve cords dilate anteriorly to form the brain. This structure is composed of a dorsal and a ventral cerebral ganglion on either side. The ventral ganglion is merely the expanded end of the lateral cords, and it is

* It should be mentioned that the above view of the nature of the elements of the nervous core is that advocated by Montgomery (loc. cit. p. 428). Bürger on the other hand (Die Nemertinen, Fauna und Flora des Golfes von Neapel Bd. XIX., 1895) supposes the densely staining elements, considered to be neuroglial processes on the above view, are the nervous fibrils, and that the so-called nerve tubules are clefts filled with fluid.

difficult to say exactly where the one ceases and the other starts. The dorsal ganglia are closely united with the ventral (Pl. I., fig. 5, and Pl. II., fig. 4). The two dorsal ganglia are connected by a dorsal commissure (Pl. I., fig. 4) and the ventral ganglia by a much stouter ventral commissure. The nervous ring thus formed surrounds the proboscis sheath, and not, as in most worms, the alimentary canal. The posterior ends of the dorsal ganglia, now no longer in contact with the ventral ganglia, are continued into the so-called cerebral organ, which will be referred to under the sense organs later.

Histologically the general structure of the brain is similar to that of the lateral cords, with the difference that the ganglion cells are not all alike. In the brain three varieties of ganglion cells may be distinguished:—

(1) Small cells of shortened pyriform shape, the deeply staining nuclei of which almost fill the cell bodies. They occur on the dorsal and ventral aspects of the dorsal ganglia (Pl. II., fig. 4), and also in the cerebral organs, and are probably sensory in function.

(2) Medium sized cells, more or less elongated and pear-shaped. These occur in the ventral brain lobes and in the lateral cords, forming the greater part of the ganglion cell layer of the latter. They vary somewhat in size, but may be distinguished from the next type by the shape of their nucleus, which is oval and not spherical, as in the

(3) Large cells. These are also of elongated pyriform shape, and are found in the dorsal and ventral ganglia, as well as in the lateral cords.

The larger ganglion cells of the last two types are probably motor in function. In some Lineidæ a yet larger type of cell may be present in the ventral ganglia, and sometimes also in the lateral cords. They possess very large axis cylinders, which have been termed neurochords. They are not present in *Lineus gesserensis.*

In addition to the central nervous system, consisting of the brain and lateral cords, various peripheral nerves may be distinguished. These may be classed under five headings:—

(1) Cephalic nerves (Pl. I., fig. 2, *cn.*), given off anteriorly from the dorsal ganglion and innervating the skin of the snout, the frontal organs, and eyes.

(2) The œsophageal nerves (Pl. II., fig. 1, *oesn.*) which come off from the hinder portion of the ventral ganglia, and may be regarded as marking the boundary between the latter and the lateral cords. Immediately after coming off the œsophageal nerves of each side unite by several commissures (Pl. I., fig. 6, *oesc.*). Behind this the nerves may be easily traced for a little way along the œsophagus, where they lie ventrally and somewhat laterally. Just before the excretory region they become broken up, though it is probable that their fine branches extend backwards and innervate the whole of the alimentary canal. By some writers these nerves are spoken of as the vagus nerves.

(3) The nervous sheath (Pl. II., fig 2, *nl.*) which forms a delicate coat lying at the same level as the side stems and completely enveloping the circular muscle layer. In the median dorsal line (Pl. III., fig. 8, *nd*) a thickening of this layer occurs. This is the median dorsal nerve which anteriorly fuses with the dorsal commissure of the brain. From this nervous sheath fine fibrils may be traced to the skin and the muscle layers of the body wall.

(4) The proboscis sheath nerve—an exceedingly fine nerve situated just beneath the circular muscle layer in the median dorsal line. It probably innervates the structure from which it receives its name.

(5) The proboscis nerves which are given off one on each side of the ventral ganglia and pass thence into the proboscis. Inside this structure they soon spread out and fuse to form a nervous sheath investing the proboscidial epithelium in the retracted state of the organ.

On the nerves of the peripheral system are found some nuclei, but these probably belong to neuroglial, not ganglion cells.

SENSE ORGANS.

The ciliated cells of the epidermis doubtless function as sensory cells, though whether the sensory elements can be distinguished apart from the ordinary ciliated cells has not been determined in the case of *Lineus gesserensis.* Some observers, however, have been able to distinguish such cells in other species. Apart from these, three forms of sensory organs are found in the present species.

(1) The cerebral organ. It has already been noticed that on either side of the head there is a groove bounded by mobile lips, reaching from the tip of the head nearly to the mouth region, and deepening as it passes backwards. At the posterior extremity of each of these head slits (Pl. IV., fig. 1, *hs.*) is a small aperture marking the opening of a fine blind canal which, taking first a backward and then a forward course (Pl. III., fig. 3, *cc.*), lies for its whole extent in close proximity to the hinder portion of the dorsal ganglion. Into it open two sets of glands. The first set (Pl. I., fig. 3, and Pl. III., fig. 3, *acg.*) opens into the canal immediately after its commencement, the second set a little further back (Pl. III., fig. 3, *pcg.*). Up to this point the epithelial lining of the canal consists of high thin columnar cells devoid of glands, but behind the opening of the posterior gland the epithelium of the ciliated canal becomes greatly changed.

When viewed in transverse section (Pl. III., fig. 1) the inner half of the canal is seen to be lined by very long cells possessing large nuclei and with an inner hyaline extremity consisting of fused cilia, at the base of which are minute deeply-stained granules. On the outer side of the canal the cells are even more highly specialised, and are five in number (as seen in transverse section), viz., a median one, two smaller ones on either side, and two very large ones again on either side of these. More than one nucleus is present in all of them. The cells of these five rows are separate at their inner ends both from one another and from the cells of the internal half of the canal. Like the latter they possess an inner hyaline portion, consisting of fused cilia projecting into the lumen of the canal. The basal portions of all these cells are without a well-marked limiting membrane, and come into close contact with the fibrous core of the posterior extremity of the dorsal ganglion. Numbers of small sensory ganglion cells of the first type (page 16) are massed round the canal (Pl. I., fig. 6, and Pl. II., fig. 4), and the projection of the fibrous core from the dorsal ganglion.

The function of this elaborate organ is still problematical. By some writers it has been supposed to contribute to the respiration of the brain lobes, though the specialised character of its epithelium and the number of ganglion cells in it would seem to lend more countenance to the view that its function is rather concerned with the elaboration of some special sensory impulses.

(2) The frontal organ consists of three small projecting patches of high columnar glandless epithelium bearing cilia (Pl. IV., fig. 1, *fr.*). The median patch is situated just above the proboscis pore with a lateral patch on either side of it. These patches are retractile, and after

preservation appear in section as small pits (Pl. I., fig. 1). Opening near them are the so-called head glands, which in *Lineus gesserensis* form a small mass of gland cells lying in the anterior portion of the snout just above the rhynchodæum.

(3) The eyes vary in number, the adult animal usually having a dorso-lateral row of about five on each side. They lie imbedded in the tissue of the snout well below the epidermis and dorsal to the head slits. Each eye consists of a deep layer of cells containing a dark brown pigment, over which is a layer of pyriform cells (Pl. III., fig 4), whose more pointed ends are drawn out into long processes which are inserted into a fine nucleated membrane. On the long processes of these ganglion (?) cells may often be seen minute deeply-staining bodies, whilst between them is a clear fluid kept in by the fine limiting membrane and forming a lens. The eyes are supplied by some of the cephalic nerves which enter them from the pigmented side. Instances may frequently be observed in which two eyes are incompletely separated, whence it may probably be inferred that their number is augmented by division of those already existing. The young *Lineus* when hatched has but a single eye on either side.

THE CONNECTIVE TISSUES.

These have been studied in the present species by Montgomery (loc. cit. p. 1), who distinguishes the following kinds:—

(1) Branched connective tissue cells with inter-cellular substance, composing the basement membrane of the external epithelium, the outer and inner neurilemma, the sheaths around the muscular fibres, the layer immediately surrounding the intestine, the layer outside the endothe-

lium of the blood vessels, and probably also the enveloping membrane of the gonads. The intercellular substance formed by these cells is structureless and of gelatinous appearance, and takes a deep colour with many staining reagents (especially hæmatoxylin or nigrosin).

(2) Pigmented connective tissue without intercellular substance. This occurs in the cutis, and consists of membraneless cells with fine branching fibrils containing greenish yellow pigment granules. It is more plentiful on the dorsal surface where the colour is darkest. The amount and distribution of this pigment probably determines the colour variety (*i.e.*, whether red or green), since a greater amount of pigment usually occurs in the red variety. On this view the red colour must be looked upon as due to the refraction of light rays coming from the greenish pigment.

(3) Mesenchyme tissue composed of bi- or multi-polar cells without intercellular substance. This tissue is much reduced in the present species, being only found in the anterior region of the body between the proboscis sheath and the œsophagus.

(4) Parenchyme tissue consisting of large, much-vacuolated cells with an outer membrane. This occurs round the dorsal and lateral blood vessels in the intestinal region (Pl. IV., fig. 2), though it is not present on the commissural vessels.

BODY CAVITY AND GONADS.

While some observers hold that no body cavity is present in the Nemerteans, others consider that it is represented by spaces sometimes found round the alimentary canal, and in which occur mesenchyme cells. Such spaces are in some species well marked with the mesenchyme cells so arranged as to form a more or less definite lining membrane. It is possible, however, that they may be due to shrinkage in the process of preservation. As has already been seen, the only space of this kind which occurs in *Lineus gesserensis* is a small one between the proboscis sheath and the œsophagus. The space between the intestine and the inner longitudinal muscle layer is small, and is occupied by connective tissue cells and their intercellular substance.

In this space occur sacs alternating with the intestinal diverticula (Pl. III., figs. 6 and 8), and with the intestinal diverticula (Pl. III., figs. 6 and 8), and lined by connective tissue cells. These are the gonads whose cavity, apparent in the young animal, becomes obliterated in the mature worm by the sexual cells which fill it, and which are probably derived from the connective tissue cells which form its lining. Each gonad possesses a duct which opens dorso-laterally (Pl. III., fig. 8, *gd.*), and which is formed partly by a prolongation of the connective tissue lining of the gonad, and partly from an ectodermal depression.

The sexes are separate, and in the breeding season, which lasts from about February till June, the female deposits her ova under stones in a long tubular gelatinous cord. In the walls of this cord are the ova contained in small flask-shaped transparent capsules (Pl. III., fig. 7). One of the gelatinous cords produced by a single female usually contains a hundred or more of these little capsules, and each capsule contains the contents of a gonad, *i.e.*, from one to seven ova, according to the size of the female. The spermatozoa of *Lineus gesserensis* possess a long pointed head (Pl. IV., fig. 4). The gelatinous cord containing the ova is said to be the joint production of the male and the female. Into it the male then proceeds to discharge spermatozoa. Soon afterwards the female deposits her ova, already surrounded by the characteristic capsule, which are then fertilized. The ova are deposited in the capsules, which are probabl secreted by the lining of the gonad.

DEVELOPMENT.*

The ova before fertilisation measure about ·3 mm. in diameter, and are opaque owing to the numerous oily yolk granules which they contain. The germinal vesicle is well marked, and in it is a large nucleolus or germinal spot. After fertilisation segmentation is complete and regular, resulting in a blastula. A segmentation cavity is already present in the 8 cell stage. The blastula is covered with cilia by whose action the young embryo is kept in constant rotation. Invagination of the blastula then takes place, and results in the formation of a typical gastrula. The differentiation between ectoderm and endoderm cells is now apparent, the latter being considerably larger. The endodermal invagination is directed somewhat obliquely (Pl. IV., fig. 9), so that the future alimentary canal lies entirely behind the blastopore, enabling one to distinguish already at this stage the anterior and posterior ends of the animal.

The ectoderm of this stage does not directly become the ectoderm of the larva, but the latter is established by a series of remarkable changes. In two small areas on either side the cells of the primary ectoderm of the gastrula divide lengthways forming palisade cells. These areas of secondary ectoderm, the cephalic and ventral

* The development of *Lineus gesserensis* has been studied more especially by Desor, Barrois, M'Intosh, and Hubrecht. The account given by the last-named is the only one based on modern methods, and has been followed in this paper.

plates, are then overgrown by the cells of the primary ectoderm (Pl. IV., fig. 7) surrounding them, so that at these four areas the ectoderm becomes two-layered, viz., a layer of secondary ectoderm covered externally by the layer of primary ectoderm, which has again become continuous (*cf.* Pl. IV., fig. 9). At the anterior end, a fifth area of secondary ectoderm, the proboscidial plate, arises, though it differs from the others in being formed by delamination, and not by sinking in (Pl. IV., fig. 9, *prp.*). The five areas of the secondary ectoderm then spread out and fuse with each other, forming a continuous coat which lies directly beneath, and subsequently becomes entirely separated from the primary ectoderm. This secondary ectoderm eventually forms the ectoderm of the adult. The primary ectoderm is cast off later, degenerates, and is utilised as food material by the embryo.

Before the fusion of the five secondary ectoderm plates, however, two invaginations of the primary ectoderm are formed on either side of the blastopore (Pl. IV., fig. 8, *corg.*). These later sink beneath the secondary ectoderm between the cephalic and ventral plates of the latter, and eventually give rise to the ciliated canals of the cerebral organs. In the process these invaginations lose their communication with the exterior (Pl. IV., fig. 10, *corg.*), but later a secondary opening is formed in each case at the surface of the secondary ectoderm.

At the time when the five plates of secondary ectoderm are commencing to appear the first traces of the future mesoderm are seen as cells budded off from both the primary ectoderm and the endoderm (Pl. IV., figs. 7, 8, 9). After the establishment of the secondary ectoderm as a continuous layer, these mesoderm cells come to be entirely enclosed within it.

Meanwhile changes have been taking place within the endoderm. Whilst the secondary ectoderm is making its appearance the hinder portion of the archenteron becomes shut off from the more anterior part by a coalescence of some of its cells (Pl. IV., fig. 9), resulting in the formation of a posterior intestinal portion with a closed cavity, and an anterior œsophageal portion whose lumen opens to the exterior by the blastopore. The last-named eventually becomes the mouth of the adult. Later the cavities of the œsophagus and intestine become secondarily continuous, but before this occurs a small lateral evagination is formed on either side of the inner portion of the œsophagus. These evaginations eventually lose their connection with the œsophagus, and acquire openings to the exterior through the body wall. In this way are established the nephridia. Thus the œsophagus must be looked upon as endodermal, and consequently the nephridia as diverticula of the archenteron. The anus is formed later at the posterior end of the intestine. During these changes the ectoderm of the proboscidial plate has formed an invagination, which will become the lining of the rhynchodæum and of the proboscis (Pl. IV., fig. 10, *p.*) The embryo now presents the appearance shewn in Pl. IV., fig. 5, and is known as Desor's larva.

The fate of the ectoderm and of the endoderm has now been traced. With the exception of the gonads, the remainder of the body is derived from the mesoderm, whose cells by this time have come together to form a continuous layer round the structures whose formation has already been described. The mesoderm gives rise to the connective tissues, muscles, nervous system, blood vessels, and proboscis sheath. The cavities of the two last are remains of the segmentation cavity. That the nervous system should be of mesodermal origin is a somewhat remarkable fact. Still it has already been seen that the mesoderm is derived in part from the primary ectoderm, and it is possible that these cells are the ones concerned in the formation of the nervous system; on which view its origin would be but ectodermal in disguise. An exception to the mesodermal origin of most of the organs was noticed above. This is the case of the gonads, which are stated to arise at a later stage as ectodermal ingrowths ventral to the level of the lateral nerve cords. The connection with the ectoderm is then lost, and the ducts are developed later above the level of the lateral nerves. The origin of the various organs has now been traced. During the later part of its stay in the egg capsule the larva lengthens considerably, until the little worm, now about 1·5 mm. long, forsakes the protection of its embryonic shelter to become an independent though microscopic unit in the teeming life around its birthplace.

The development through the larva of Desor as sketched above is not the only form which occurs in the family of the Lineidæ. In some other species of Nemerteans a free swimming pelagic larva, known as the Pilidium, is formed, and a slight knowledge of its developmental history throws some light upon the peculiar formation of the ectoderm in Desor's larva. A typical gastrula is formed, which then acquires a dorsal tuft of long, fused cilia and two lappets produced by ectodermal folds hanging down laterally on either side of the mouth. From its fancied resemblance to a helmet at this stage the larva derives its name.

The young worm is then developed inside the Pilidium, in whose ectoderm five invaginations now make their appearance round the mouth, viz., two paired and one anterior median unpaired. These invaginations lose their connection with the outer ectoderm of the Pilidium, and grow together to surround the endoderm of the larva. When this process is complete the body wall of the animal, exclusive of the mesoderm, now consists of four layers. Externally is the ciliated ectoderm of the larva, and internally the endoderm, whilst between these are two layers of ectoderm formed by the fused invaginations. Of these two layers the inner becomes the ectoderm of the adult worm, and corresponds to the secondary ectoderm of Desor's larva. The young Nemertean continues to develop, and, when full grown, parts company with the remains of the Pilidium, which then consist of the original outer ectoderm and the outer layer of the fused ectodermal invaginations. Hence the discarded layer of primary ectoderm in Desor's larva corresponds to the ectodermal shell of the Pilidium which is cast off when the young Nemertean escapes.*

In several important respects the process of development by Pilidium is said to differ from that by the larva of Desor. Among these may be more especially mentioned the origin of the nervous system and of the nephridia. The former is said to arise directly from the secondary ectoderm as local thickenings of this layer, whilst in the larva of Desor it has already been seen to take its origin from the mesoderm. Again in Pilidium development there is said to be an ectodermal œsophageal invagination when the nephridia arise, and these are consequently not of endodermal origin as in Desor's larva.

There are also other differences, but the above are sufficient to show that Hubrecht's account (which has been followed above), though in its original form full and

* An excellent account of Pilidium development, illustrated by numerous coloured diagrams, is given by L. Joubin in Les Nemertiens, Traité de Zoologie de R. Blanchard, fascicule XI. Paris, 1897.

circumstantial, should be accepted with caution until confirmation has been received from other sources.

REGENERATION.

Though observations on the regeneration of lost parts do not exist in the case of *Lineus gesserensis*, yet in a closely allied species, *Lineus sanguineus*, interesting facts in this connection were brought to light by M'Intosh. When kept in captivity, examples of this species shew a tendency to rupture into many pieces. Each of these fragments may develop into a complete worm, both anterior and posterior ends being formed anew.

PARASITES.

Like most Nemerteans, *Lineus gesserensis* is frequently infested with Sporozoan parasites. These occur chiefly in the intestinal region attached to the epithelium of the alimentary canal and hanging freely into its lumen. A curious large Mesozoan parasite has also been recorded in this species (*Rhopalura*). It is found burrowing in the body wall, and its presence may be recognised, according to M'Intosh, "by the perforated and honey-"combed appearance of the dorsum of the affected animal, "whose textures seem to be the seat of the workings of a "microscopic *Tomicus typographicus*."

SYSTEMATIC POSITION.

The Nemerteans are divided by Bürger into four orders based mainly upon the number of muscle layers in the body wall, and the position of the lateral nerve cords with respect to these layers. Briefly these orders, with the British families and genera belonging to each, are as follows:—

I. PROTONEMERTINI.

Two muscle layers in body wall, *i.e.*, external circular and internal longitudinal. The lateral nerve cords lie outside the circular layer. Proboscis without stylets. Mouth behind brain.

Fam. CARINELLIDÆ.

Genus. *Carinella.*

II. MESONEMERTINI.

Two muscle layers in body wall, *i.e.*, external circular and internal longitudinal. The lateral nerve cords lie in the midst of the longitudinal layer. Mouth behind brain. Proboscis without stylets.

Fam. CEPHALOTHRICIDÆ.

Genera. *Cephalothrix*
Carinoma.

III. METANEMERTINI.

Two muscle layers in body wall, *i.e.*, external circular and internal longitudinal. The lateral nerve cords lie beneath the longitudinal layer. Mouth in front of brain. Proboscis armed with stylets.

A. PRORHYNCHOCŒLOMIA.

Body long and thin. Proboscis and proboscis sheath much shorter than body.

Fam. EUNEMERTIDÆ.

Eyes present. No otocysts.

Genus. *Eunemertes.*

Fam. OTOTYPHLONEMERTIDÆ.

No eyes, but one or more pairs of otocysts ventral to brain.

Genus. *Ototyphlonemertes.*

B. HOLORHYNCHOCOELOMIA.

Body usually short. Proboscis at least as long as body. Proboscis sheath reaches into hinder third of body.

Fam. TETRASTEMMIDÆ.

Four eyes. Cerebral organs in front of brain. Dioecious or hermaphrodite.

Genera. *Prosorochmus.*
Tetrastemma.

Fam. AMPHIPORIDÆ.

Numerous eyes. Cerebral organs generally behind brain. As a rule members of this family are considerably larger than those of the preceding.

Genera. *Amphiporus.*
Drepanophorus.

Fam. MALACOBDELLIDÆ.

Parasitic in Lamellibranchs. Sucker at posterior end.

Genus. *Malacobdella.*

IV. HETERONEMERTINI.

Three muscle layers in body wall, *i.e.*, outer longitudinal, middle circular, and internal longitudinal. Proboscis without stylets. Mouth behind brain.

Fam. EUPOLIIDÆ.

Without head slits.

Genera. *Eupolia*
Valencinia.
Oxypolia.

Fam. LINEIDÆ.

With head slits.

Genera. *Lineus.*

Euborlasia.

Micrura.

Cerebratulus.

Micrella.

The genera of the Lineidæ set down above are exceedingly difficult to define. The three genera *Micrura*, *Cerebratulus* and *Micrella* (together with the exotic genus *Langia*) agree with one another in the possession of a slender tail filament at the posterior end of the body. For this reason they have been grouped together as Micruræ in opposition to the rest of the family, which are known as the Amicruræ. It is very doubtful, however, whether this caudal appendage is homologous in all the instances in which it is found, for in some cases the anus opens at its tip, whilst in others it opens at its base either just above or just below it. It also presents other anatomical differences in different species.

The body form is regarded by some as affording a character upon which to base generic distinctions. Especially is such the case in *Cerebratulus*, of which genus the species are often characterised by their breadth, due chiefly to the sides of the animals being flattened out to form a kind of fin known as the side folds. Gradations between such a state and a more or less circular outline in section are found, so that the absence of well-marked side folds does not necessarily preclude a species from being relegated to this genus. *Cerebratulus* is also supposed to be characterised by a fine layer of diagonal muscles just outside the circular layer. This, however, is often absent. In fact at present the three genera, *Lineus*, *Cerebratulus* and *Micrura* are exceedingly illdefined. Many anatomical differences are found in the family, amongst which may more particularly be mentioned the following:—

(*a*) A diagonal muscle layer, neurochord cells, eyes, and frontal organ may be either present or absent.

(*b*) A well-marked cephalic vascular head loop may be present, or the cephalic vessels may form an anastomosing network.

(*c*) The excretory system shews great variations in its backward extent; the position of the tubules may be dorsal or ventral, or both; they may reach forward to the cerebral organ, or may commence some way behind it. Also some species possess a number of ducts whilst only one pair is present in others.

In the majority of the Lineidæ, and indeed in many British forms, we are as yet in ignorance with regard to many of these points, and until they have been determined it is useless to attempt to place the classification of the family upon a more satisfactory basis.

Explanation of Plates.

Reference Letters.

acg. anterior gland of cerebral organ.
bc. buccal vascular commissure.
cbv. commissural vessel between *dv* and *lbv.*
cc. ciliated canal of cerebral organ.
cmc. circular cephalic muscles.
cml. longitudinal cephalic muscles.
cn. cephalic nerve.
corg. cerebral organ.
cugl. glandular cutis.
cvl. cephalic vascular loop.
dc. dorsal commissure of brain.
dg. dorsal ganglion.
dv. median dorsal blood vessel.
ep. epithelium.
exd. excretory duct.
ext. excretory tubules.
fr. frontal organ.
gc. ganglion cells.
gd. gonidial duct.
hs. head slit.
id. intestinal diverticulum.
iep. intestinal epithelium.
lbl. lateral blood lacuna.
lbv. lateral blood vessel.
m. mouth.
mc. circular muscle layer.
mcp. circular muscles of proboscis.
mcr. muscle cross.
mdv. dorso-ventral muscles.
mli. internal longitudinal muscle layer.
mlo. external ditto.
mlp. longitudinal muscles of proboscis.
n. nerve to eye.
nd. median dorsal nerve.
nl. nervous layer.
nlp. nervous layer of proboscis.
nuc. nuclei.
ocg. ganglion cell (?) layer of eye.
oes. oesophagus.
oesc. oesophageal nerve commissure.
oesl. oesophageal vascular lacunae.
oesn. oesophageal nerve.
oep. oesophageal epithelium.
ogl. gland cells round oesophagus.
ov. ovary.
p. proboscis.
par. parenchymatous cells.
pcg. posterior gland of cerebral organ.

pep. proboscis epithelium.
pg. pigment layer of eye.
pn. proboscis nerve.
ps. proboscis sheath.
rd. rhynchodaeum.
rhc. rhynchocœlom.
rhce. rhynchocœlomic epithelium.
sdg. superior lobe of dorsal ganglion.
ss. lateral nerve.
vc. ventral commissure.
vep. epithelium of blood vessel
vg. ventral ganglion.

Plate I.

Fig. 1. Transverse section through the tip of the head. × 60.

Fig. 2. Transverse section taken between brain and tip of snout. × 45.

Fig. 3. Transverse section through hinder part of brain, where the anterior gland of the cerebral organ opens near the end of the head slits. × 60.

Fig. 4. Transverse section through dorsal commissure before the two limbs of the cephalic vascular loops have fused ventral to the proboscis sheath. × 45.

Fig. 5. Transverse section through brain at a level between 4 and 3. × 45.

Fig. 6. Transverse section through level of cerebral organ, buccal vascular commissure and œsophageal nervous commissure.

Plate II.

Fig. 1. Transverse section through mouth region. The œsophageal vascular lacunæ are just commencing. × 45.

Fig. 2. Transverse section through about the middle of the œsophageal region. × 45.

Fig. 3. Transverse section of epithelium from anterior intestinal region. × 300.

Fig. 4. Longitudinal vertical section through brain taken rather to one side of the median line. × 45.

Fig. 5. Transverse section through hinder region of proboscis. The circular muscles and nervous layer have both disappeared. × 120.

Fig. 6. Transverse section through proboscis at its widest—about the middle. × 80.

Fig. 7. Longitudinal median section through anterior end, shewing the relations of the proboscis to the rhynchodæum and rhynchocœlom when retracted. × 45. Somewhat schematic.

Plate III.

Fig. 1. Transverse section through so-called ciliated canal of cerebral organ, shewing the seven large external cells and the internal homogeneous cell layer all with crystalline ends formed from fused cilia projecting into the lumen. × 300.

Fig. 2. Portion of intestinal epithelium, shewing the circular refractive bodies enclosed in the elongated ciliated cells. × 168.

Fig. 3. Schematic longitudinal horizontal section through the cerebral organ of a Heteronemertean. (After Bürger).

Fig. 4. Section through eye just anterior to the entry of the nerve into the pigmentary layer. × 240.

Fig. 5. Section through blind end of an excretory tubule (left portion), shewing elongated cilia. × 300.

Fig. 6. Longitudinal horizontal section through intestinal region, shewing the intestinal diverticula alternating with the gonads. × 45.

Fig. 7. Flask-shaped egg capsule, containing a single embryo in the morula stage. (After M'Intosh.) × 25.

Fig. 8. Transverse section through intestinal region passing between two diverticula. × 45.

Plate IV.

Fig. 1. Schematic figure, shewing the relations of the various systems in the anterior end of the animal as viewed from above. The proboscis and its sheath, the œsophageal nerves and the buccal vessels have been omitted.

Fig. 2. Transverse section through lateral blood vessel. On the side of the alimentary canal the parenchyma cells are smaller and complete. On the outer side no cell wall is to be distinguished away from the vessel. × 168.

Fig. 3. Portion of œsophageal epithelium from a transverse section. Three kinds of gland cells are seen among the ciliated epithelium and below it:—(*a*), (*β*), and (*γ*). (for explanation vide text). × 168.

Fig. 4. Two spermatozoa (after M'Intosh). × 700.

Fig. 5. Larva of Desor as seen from the ventral surface. The outer ciliated coat is not yet shed. (After Barrois).

Fig. 6. Young Lineus just hatched. × 40. (After M'Intosh).

Figs. 7-11. Diagrammatic sections through larvæ of Lineus at different stages. (After Hubrecht).

Fig. 7. Transverse section, shewing the secondary epiblast of the cephalic plates (*cp.*) gradually overgrown by the primary (*prep.*). The proboscidial plate (*prp.*) arises antero-dorsally by delamination.

Fig. 8. Transverse section of slightly later stage, shewing the two invaginations from the primary epiblast on either side of the blastopore, which will eventually give rise to the cerebral organs (*corg.*).

Fig. 9. Longitudinal section through a stage slightly younger than 7. The archenteron is subdivided into intestine (*int.*) and œsophagus, which do not communicate.

Fig. 10. Horizontal section of older embryo. Proboscis now invaginated and mesoblast accumulating. The secondary epiblast, consisting of proboscis, cephalic (*cp.*) and ventral plates (*vp.*), now forms the external surface of the worm, having sunk in, and become separated from the primary epiblast (*prep.*). The section corresponds to the stage shewn in figure 5.

Fig. 11. Median longitudinal section through somewhat later stage. The hinder portion of the proboscidian mesoblast is now attached. The œsophagus and intestine communicate. Rhynchocœlom now apparent (*rhc.*).

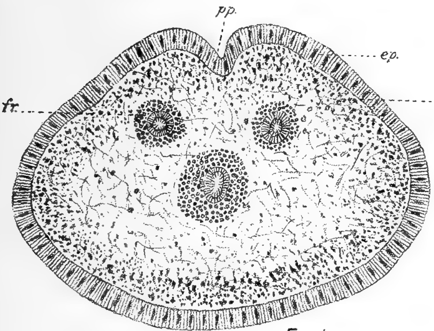
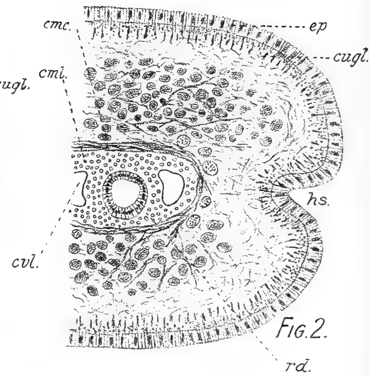


Fig. 1.



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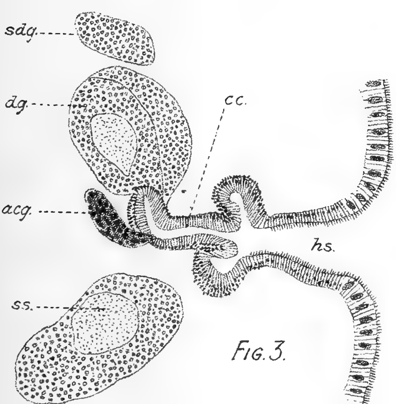


Fig. 3.

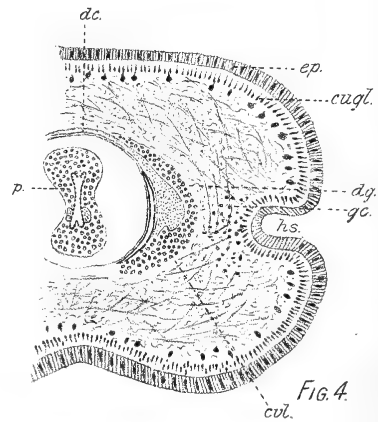


Fig. 4.

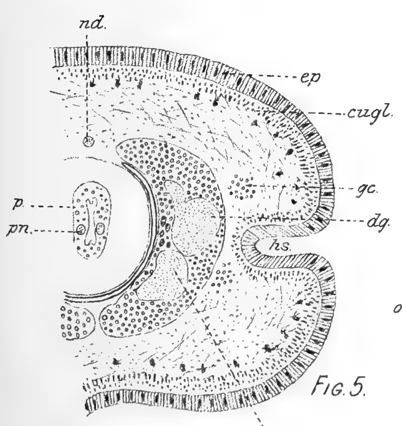


Fig. 5.

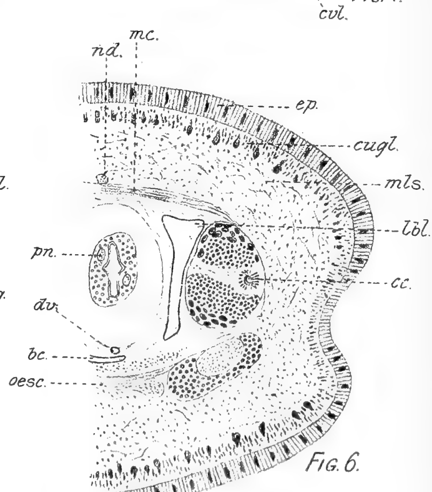
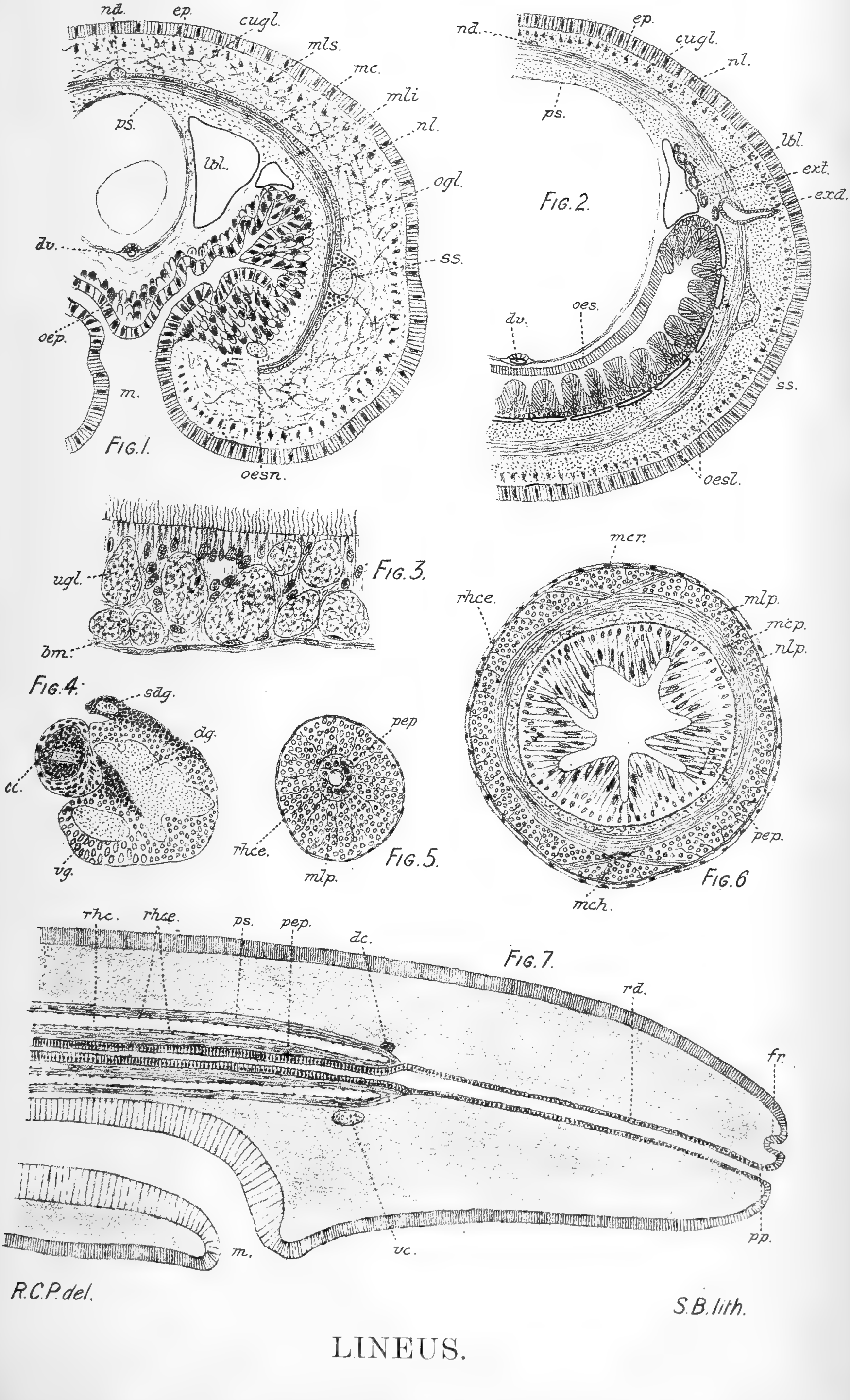


Fig. 6.

R.C.P. del. S.B. lith.

LINEUS.

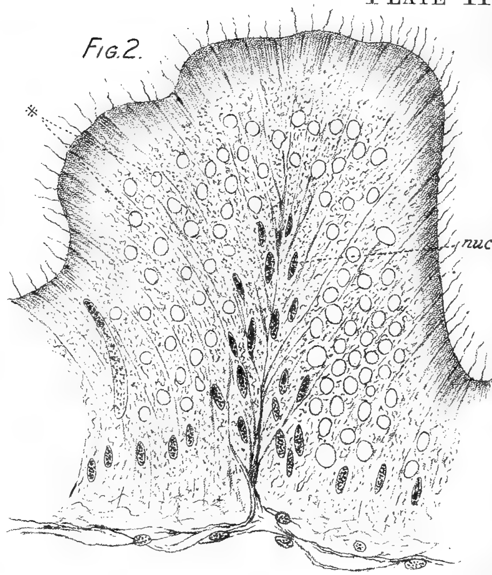


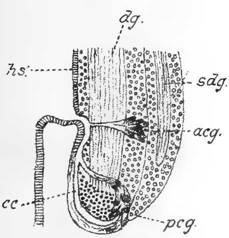
R.C.P. del. S.B. lith.

LINEUS.

Fig. 1.

Fig. 2.





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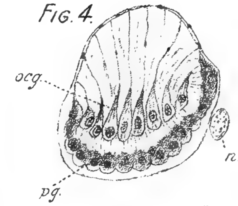

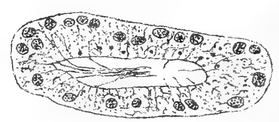

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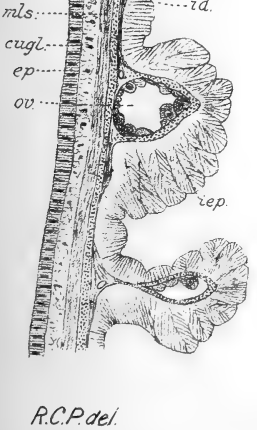

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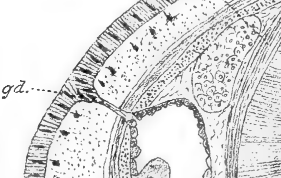

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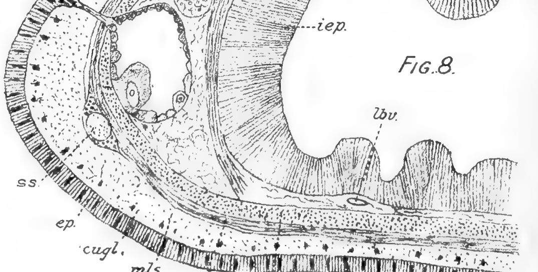

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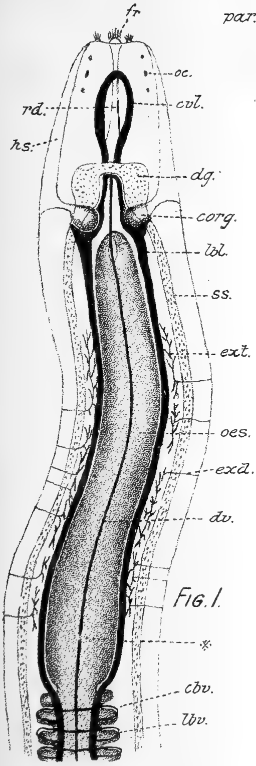

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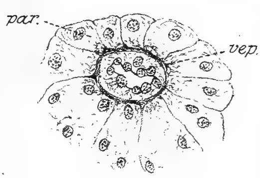

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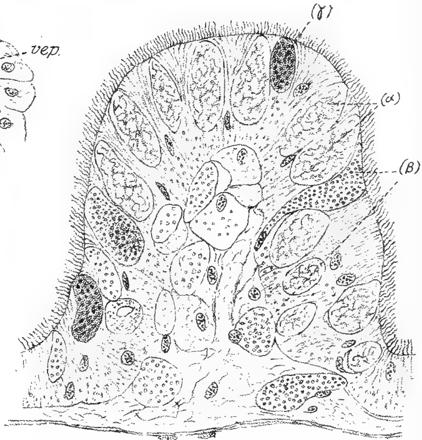

Fig. 3.


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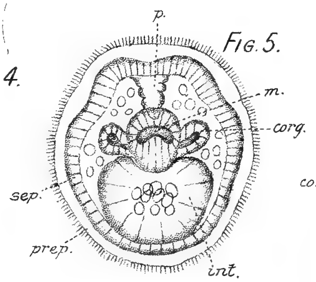

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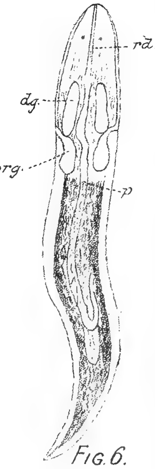

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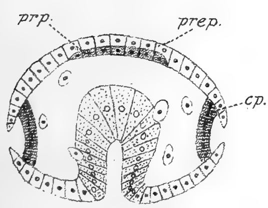

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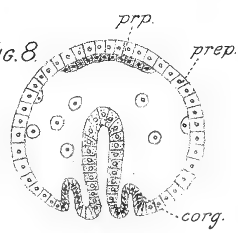

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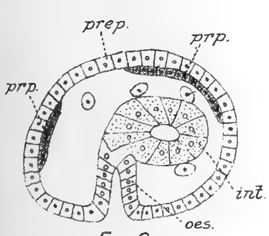

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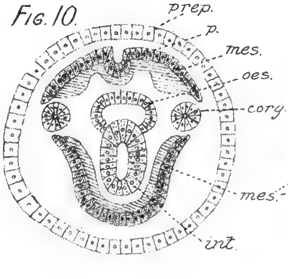

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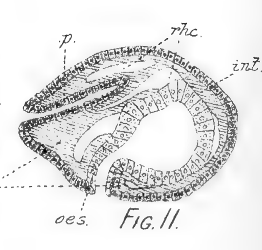

Fig. 11.

R.C.P. del. S.B. lith.

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THE METHODS AND RESULTS OF THE GERMAN PLANKTON INVESTIGATIONS, WITH SPECIAL REFERENCE TO THE HENSEN NETS.

By J. T. Jenkins, D.Sc.

[Read May 10th, 1901.]

Introduction.

At the suggestion of Professor Herdman I have undertaken to draw up a brief but I trust sufficient account of the methods employed by the German investigators for the estimation of the Plankton, that is, the floating, as distinguished from the swimming, organisms which occur at all times but in varying abundance in all parts of the seas and oceans. I do this the more readily as I have had ample opportunities of practically making myself acquainted, during the past twelve months, with the methods of plankton investigation as at present carried out in Kiel, and as no account of these methods yet exists in English.

A short account of the *results*, which are of great and far-reaching importance, already obtained by the German workers, has also been appended; but this latter part is somewhat brief, and serves more as an indication of the direction in which results have been already obtained than as a summary of the results themselves. Sufficient references are, however, given to the literature to enable any one who might care to devote further study to the question to find a full and adequate account of the conclusions already obtained. The plankton estimation methods of the Germans, the credit for initiation of which is due to Hensen (1),* differ from and mark an advance on the methods hitherto employed in England, inasmuch as no attempt is made in the latter country to arrive at a quantitative as distinguished from a qualitative result.

The questions that Hensen attempts to answer are, 1, What does the sea contain at a given time in the shape of living organisms in the plankton? and, 2, How does this material vary from season to season and from year to year?

It may be pointed out that the results obtained by the German investigators are largely due to the liberal attitude taken by their Government with regard to subsidising scientific investigation of problems connected with the Sea-Fisheries. It is to be hoped that the Irish Sea may be subsequently investigated in like manner. A comparison with the results already obtained for the North and Baltic Seas could not fail to be of interest and to yield important results.

In the preparation of this paper, which is, of course, largely a compilation from the literature already published in German (a list of the more important works is appended), I have received much assistance from Professor Brandt, to whom my best thanks are due both for the assistance given me and for permission to photograph the apparatus at present in use in the Zoological Institute at Kiel. In addition, I have to thank Professor Vanhöffen and Dr. Apstein for their unfailing readiness to assist me in matters of difficulty.

Of the figures, numbers 2, 3 and 6 are taken, by permission, from Dr. Apstein's "Süsswasser Plankton" (5). Figs. 8 and 9 are from Prof. Brandt's work on "Die Fauna der Ostsee" (7). Fig. 10 is from Prof. Hensen's

* The numbers in parentheses refer to the list of papers at the end (p. 341).

work on the quantitative estimation of the smaller plankton organisms (11). The other figures are reproductions of photographs that I have taken of the apparatus as at present in use.

The Nets and Methods.

The nets devised by Hensen for the quantitative determination of the plankton are of two kinds, vertical and horizontal, according to the way they are used. Of these the vertical alone are used, the difficulties in the case of the horizontal nets being at present insuperable. The principle of the use of the vertical net consists in that it is, in the form of an inverted truncated cone, lowered perpendicularly in the water to a required depth, and then raised to the surface also perpendicularly. By this method a cylindrical column of water filters through the net, and its planktonic contents are captured. Now the volume of this cylindrical column of water can be calculated since the depth to which the net is sunk is known, as is also the area of the net opening. The first and most important requisite of the Hensen net is that it should capture the whole of the plankton in an exactly known volume of water, so that on every occasion not only must the whole of the plankton remain in the net, but the exact volume of water which has filtered through must be calculated.

It is perfectly obvious that not so much water passes through the net as would pass through a ring of equal diameter to that of the mouth of the net, which had nothing attached to it. It is also clear that a square centimetre of the net would let through more water if it were composed of a single mesh than if, as is really the case, it is composed of a large number of minute meshes, each bounded by a square of silk fibre. Therefore it is important to know, for each variety of the silk bolting cloth of which the net is composed, how much water for a given pressure and in a given time passes through a square centimetre. Hensen has with this object in view constructed a very ingenious apparatus and by means of numerous experiments has calculated the filtration capacity of each net-substance (1. page 12). In addition to these experiments another set is necessary in order to determine the filtration capacity of the net itself, and in order to make this calculation easier the net must be exactly conical, and to that end great care must be exercised in its construction. Even then an exceedingly laborious and difficult calculation is necessary for each separate net. From the depth of water to which the net is sunk, from the quantity or volume of water through which it passes, from the speed with which it is drawn up, and from the filtration capacity of the net substance and of the net itself, Hensen has finally calculated what fraction of the water column through which the net has been hauled passes through the net itself, and what fraction has escaped over the edge of the ring. The number of organisms captured in the net is thus brought into relation with the column of water through which the net has passed, and so with any given portion of the sea.

By means of a closeable net, observations can be made at any depth required. The net is lowered vertically to a given depth while open, but in a collapsed condition, so that practically nothing gets into it through the ring. The water that passes in at first does so through the meshes of the net. Then it is hauled up vertically through a given height, and by means of a weight which runs down the rope it becomes closed, and is then hauled on board so that the organisms in the water at the required depth, say from 1,000 to 500 metres, are captured.

THE VERTICAL NET.

The large vertical plankton net consists essentially of three parts :—1. The conical head piece (Fig. 1, *A*). 2. The net itself, *B* ; and 3, a metal cylinder or bucket suspended at the apex of the net, *C*.

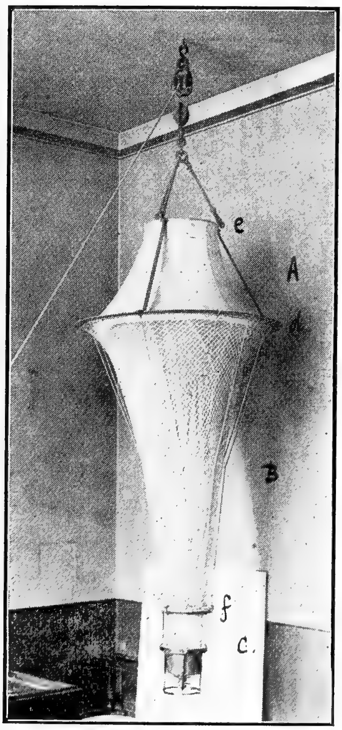

FIG. 1.

The newest form of the net is here described, and the description therefore differs in some details from that given by Hensen (1).

The head piece consists of a circular iron ring, *e*, of 38 cm. diameter, so that the area of the mouth of the net is one-tenth of a square metre, to which are attached three iron rods, each 40 cm. long, which are in turn attached to another broad and flat iron ring, *d*, of 100 cm. diameter. The iron rods are at their upper ends bent into hook-like rings, to which ropes are attached. The whole of this head piece is covered with fustian. This part serves to prevent mud or slime getting into the net when it is lowered on to very soft ground. The edge, *d*, sinks to some extent in the mud, but only when the edge, *e*, sinks below the surface of the mud can the latter enter the net. Only very occasionally was the head piece found to be not sufficiently high. It is also useful, as it serves to prevent part of the catch from overflowing the ring *d*, for instance, should the ship during the time the net is out sink to the trough of a wave, the net might at the same time be raised and its contents be spilt. The net is also liable to collapse in a short choppy sea. The space in the headpiece serves to prevent these accidents, as the volume of water momentarily jerked out of the net proper is retained in this space and subsequently filters through the net itself. To the iron ring, *d*, is suspended a rope sewn on with linen, and from this the silk net passes to a brass ring. The net has a funnel-shaped form. An improvement would be effected if it were possible to make it cylindrical.

To the brass ring, *f*, a filtering cylinder or bucket is suspended. After many experiments Hensen came to the conclusion that the most suitable material for the net itself was silk bolting cloth or gauze ("Müllergaze"), being the material used by millers to separate flour of different qualities. This silk bolting cloth is numbered according to the meshes of the silk. There are twenty varieties, of which the highest number has the smallest mesh. The web is very ingeniously constructed, so that the threads of the network cannot become displaced, and the areas of the meshes are, as a rule, very similar. As a rule the mesh numbered 20 has been used, and for this number and 5 the number of meshes per square centimetre and the length of a side of a single mesh are given. For number 5 each square centimetre has on the average 763 meshes, and the length of each mesh is 0·2 mm. In number 20 the number of meshes is 5,926 and the length of side 0·05 mm. With the latter mesh most of the Diatoms would be captured, though it would occasionally happen, when they approached the mesh in the direction of their longitudinal axis, that they slipped through.

The silk bolting cloth must be so arranged between the two rings that it cannot become folded. It is advisable in the first place to cut out a paper pattern, the silk cloth can then be cut accordingly. The net should have the form of a truncated cone (Fig. 2).

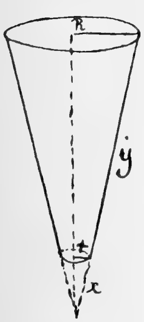

FIG. 2.

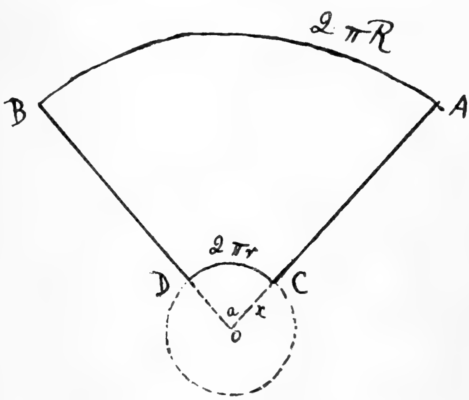

FIG. 3.

Let R and r be the radii of the larger and smaller rings respectively, and let y be the height of the covering; let x be the length of the truncated portion. These are the dimensions chosen for the particular net. It is necessary to find the angle to which the cloth must be cut. This is calculated as follows:—

$$x : x + y = r : R.$$

$$\text{That is} \quad x = \frac{ry}{R - r}$$

Now suppose the conical mantle is unrolled (Fig. 3). Then it follows that the segment of the circle subtended by the angle a bears to the circumference of the circle the ratio of a to 360°.

$$\text{Consequently} \quad \frac{2x\pi}{2r\pi} = \frac{360}{a}$$

$$\text{Therefore} \quad a = \frac{360r}{x}$$

For the large plankton net used in marine investigations R is 50 cm., r is 10 cm., and y is 144 cm.

When the net is cut out according to the above pattern, an extra inch of cloth must be allowed on all sides, so that the edges $A\ C$ and $B\ D$ (fig. 3) may be sewn together by means of a fine needle. The silk cloth along the line $A\ B$ is sewn on to the upper ring, and along the line $C\ D$ it is fastened between the metal cylinder and a brass ring.

There are several varieties of the metal cylinder, or bucket, that is attached to the apex of the net. One only is described here (Fig. 4). The upper part of the cylinder is formed of a brass ring, *B*, which by means of three screws, *s*, is fastened on to a brass ring of similar circumference at the apex of the net. The walls of the upper part of the cylinder are composed of silk bolting cloth, *c*. The lower part of the cylinder is of brass, which is painted green. By means of a turncock, *t*, the catch can be run off into the filtrator.

The filtrator (Fig. 5) consists of four principal parts, a metal base (*m*), a removable glass plate (*g*), the filter itself

(*F*), and a metal funnel (*D*), which fits exactly into the filter. The catch is carefully filtered, and then the metal funnel (*D*) is removed. On unscrewing the screw (*s*) the brass rod (*b*) can be moved downwards, while the arms (*a*) are moved upwards, and then the filter and glass plate can be removed. The catch remains on the glass plate.

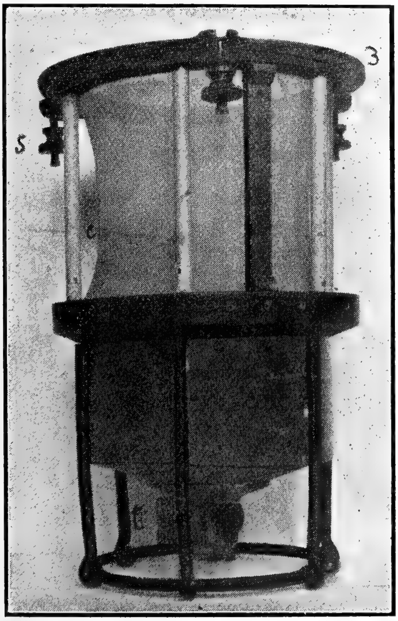

FIG 4.

The use of the vertical net at sea is attended with many difficulties. In the first place the ship must be brought to, and even then it is impossible that a large ship can remain perfectly still during the time necessary for lowering and hauling in the net. The strain on the net while being lowered and drawn up is controlled by means of the apparatus well known in dredging as an "accumulator." This apparatus consists essentially of two iron rods bound together by strong caoutchouc bands, and fastened to a spar attached to the fore mast. To the under end of the accumulator a pulley is attached, over which runs the rope attached to the net. The elasticity of the caoutchouc regulates the speed at which the net is

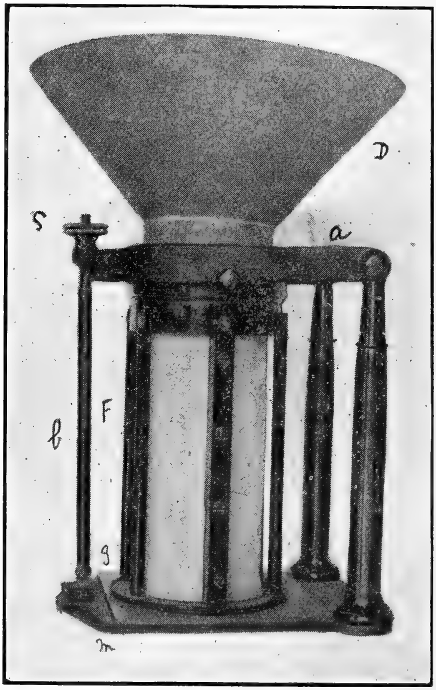

FIG. 5.

hauled in, and the degree of extension of the caoutchouc bands gives one an idea of the strength of the pull, so that one can avoid the breaking of the rope and the loss of the valuable net.

The washing down of the plankton into the metal cylinder at the base of the net is important, as when the net is first hauled up a large quantity of the catch remains lodged just above the lower ring (Fig. 1, *d*). The washing is best accomplished by directing a stream of sea water on to the outside of the net by means of a hose, or if that is impracticable by throwing buckets of water on to the net, care being taken that nothing enters the net through the ring.

The Horizontal Net.

In addition to the vertical net a horizontal net has been devised, that is to say, a net which is towed along through the water in a horizontal direction, with the opening of the net forward. This net can only be used in the upper layers of the water, and when the ship is passing over a certain definite course, the length of which is given by the log. The construction and use of this net also presents many difficulties, the chief being the strong pull brought to bear on the net owing to the variable speed with which it is drawn through the water. An alternative method to the use of this net is to pump up the water on deck by means of a steam pump, and there filter it.

Preservation of the Catch.

The catch is first of all freed from sea water in the filtrator, in which similar silk bolting cloth to that of the net is used. Several kinds of preservative fluids have been recommended. Hensen first of all tried picrosulphuric acid, but this has proved unsatisfactory. Carbonate of lime is dissolved out by this reagent, and the shells of Foraminifera are entirely destroyed. In addition the exoskeletons of the Copepoda also contain calcium carbonate, which is dissolved out. Under certain conditions Flemming's solution (chromo-aceto-osmic acid) may be used, but an excess of osmic acid should be avoided. Perhaps the best preservative is alcohol. This had better be used at first in a weak solution. The strength of the solution can be subsequently increased to the point desired.

The Estimation of the Catch.

The most difficult part of the whole undertaking is the work on land, consisting, as it does in the estimation of the catch in so exact a manner that the plankton in the sea in different places or in the same place at different times may be quantitatively compared. This estimation may be conducted in several different ways, each of which is summarised and discussed by Hensen.

There are four chief methods of estimation, namely:— 1. Volume estimation. 2. Estimation by weight. 3. By chemical analysis. 4. By enumeration of the individual organisms.

Taking first of all the method of estimation by volume, we find that the simplest method is by allowing the plankton to settle down in a glass vessel. The catch is first of all thoroughly shaken up in alcohol in a glass measuring cylinder, and allowed to stand for at least twenty-four hours. This shaking up had better be centrifugal when the plankton contains a large number of Diatoms or Peridineæ, as the subsequent deposition of these organisms is thereby facilitated. At the end of this time the plankton material has settled down at the bottom of the vessel, and forms a more or less deep layer. The depth of the layer can then be read off in centimetres, which are marked on the outside of the glass cylinder. It is of the utmost importance that the catch should remain perfectly still, because the least disturbance causes the layer of deposit to become thicker. By this means the crude or rough volume ("Rohvolumen" of Schütt) is obtained. The results obtained by this method can be readily compared with one another, but do not by any means give the true volume, because a certain amount of fluid occupies the spaces between the individual organisms.

It is possible that the plankton on several different days might yield like results according to this method, and yet be essentially quite different. For instance, the plankton might be one ccm. per day for several successive days. Then according to the volume estimation method one would be constrained to say that the plankton had remained the same. The enumeration of the individual constituents might however show that while the total volume had remained the same, the individual species had undergone a remarkable variation. Hence the importance of the last of the four methods, the estimation by counting. The presence or absence of certain forms makes a great difference in the volume of the catch, which may be out of all proportion to their importance for the particular object of the experiments. Again, certain forms take a much longer time to settle down than others. Catches in which Dinoflagellata preponderate settle down very rapidly, and only require a few hours. Copepoda also settle down quickly, and after twenty-four hours a correct result can be obtained. The Diatomaceæ are very troublesome, and when they are present in large quantities they tend to nullify the results, and a true estimation of the volume can only be obtained after waiting for a very long time. When Salpæ and similar animals are present, the estimation becomes so imperfect that the large individuals require to be separately estimated.

Another objection to the estimation of volume by this method is that a varying amount of fluid fills up the spaces between the organisms. An attempt has been made to avoid this objection in the second method of volume estimation.

According to this method the catch is filtered through the finest silk cloth. Filter paper is of no use, as so many organisms remain immovably attached to it. The damp mass of the plankton is then introduced into a glass measuring cylinder, in which an exactly known volume of alcohol is contained. The height of the mixture of plankton and alcohol is now measured. The difference between this and the previous measurement gives us, of course, the volume of the catch. This method is good, but not always practicable because on account of the extremely small catches occasionally made there is hardly any appreciable difference in the two measurements. This method gives what Schütt terms the "Dichtes Volumen." There is yet another way of arriving at the "Dichtes Volumen." The volume of the catch and fluid is first of all measured. Then the catch is filtered, and the filtrate measured. The difference gives, of course, the volume. This method is applicable for catches that consist of microscopic material. Hensen considers it gives inaccurate results. The only way of arriving at the true volume of an organism, that is the sum of the volumes of the individuals without the adhering particles of fluid, would be to estimate the average volume of an individual of the species, then count the number in the catch, and multiply the average volume by the number in the catch. This estimation is, however, too difficult, and requires too much time to be practicable. The absolute volume, that is the volume of the dry substance, would give us the most complete idea of the volume of a plankton collection. No method has as yet been devised for its estimation. The second method, that of weight estimation, is very simple, but has gradually been replaced by the third method, that of chemical analysis. The weight estimation, when practicable, gives us the best estimation of mass. It has, however, one decided disadvantage, and that is any material investigated in this way is invariably destroyed, so that it cannot be employed in cases where it is desired to preserve the material, as in the case of oceanic expeditions which have been fitted out at great cost.

The third method, that of chemical analysis has been developed by Brandt (7). The method was also employed by Hensen in his first plankton estimation work. The results of these two methods are described further on. The methods are briefly:

1. The weight in the damp condition, in addition to the volume of the mass after settling down.
2. The dry weight.
3. The weight of ash. The difference between 2 and 3 gives the weight of dry organic substance.
4. The percentage of silica. Obtained by weighing the residue insoluble in water and acids.

These methods may either be employed for the whole of the catch or for certain constituents of the same as, for example, for Copepoda or *Ceratium*.

For chemical investigation only fresh material or material preserved in alcohol can be investigated. By the use of all other preservatives either some of the substance of the catch becomes lost or destroyed or else some of the preservative medium remains behind and vitiates the results. For killing and preservation pure rectified spirit (70 per cent.) was found most suitable, and for the preservation, bottles and flasks with glass stoppers must be used. If it is wished to analyse a separate portion of the catch, the separation of such portion must be made before the organisms are killed. This can be done by the use of silk cloth of different sized meshes. A great difficulty in the chemical investigation method is the getting rid of the salt water which adheres to the organisms. In the filter most of the water filters through, but a certain amount invariably remains behind. The difficulty may be avoided in two ways, either by washing the organisms on the silk cloth with fresh water or by making, by means of a chlorine estimation, an estimate of the amount of salt retained on the average in a catch of given volume or weight. The former method is the more successful one.

For the dry weight estimation the total catch is first of all dried in a water bath at a temperature of 100° C. Then it is placed in a desiccator containing strong sulphuric acid until the weight becomes constant. Then it is weighed by means of a Bunge's balance to the nearest 0·0005 gram.

The analytical methods consist of (1) Estimation of carbon and hydrogen. 2. Estimation of nitrogen. 3. Ether extract. 4. Estimation of ash. 5. Estimation of chlorine. 6. Estimation of silica. Occasionally the quantity of chitin, cellulose or the soluble carbohydrates were estimated. A detailed consideration of these methods is beyond the scope of the present summary.

The last and perhaps the most satisfactory method of investigation is that of the enumeration of the individual constituents of the plankton. This method gives us a far better idea than any other of the nature and variability of the plankton. It is obviously impossible to count all the individuals of the catch, as the following facts prove. On one occasion Hensen found in one cubic metre of water from Kiel harbour 13 million individuals of *Ceratium tripos,* and on another occasion 102 million *Rhizosolenia semispina.* In the first place the excess of the preservative fluid is decanted off, and the catch diluted with water until a given volume is reached. This is the first dilution. If the catch has been preserved in alcohol, the latter must be thoroughly washed out with water, and this operation takes several days. Suppose the volume of the catch has been diluted with water to 50 ccm., it is evident that in each ccm. of this dilution the different organisms are present to a very varying extent. When the volume has been thoroughly shaken up, we find perhaps in one ccm. one *Leptodora* and 300,000 *Melosira*. The examples given in the estimation detailed below are from fresh water plankton. An even greater variation occurs in the case of salt water organisms. It may here be mentioned that the method of enumeration and the forms employed for entering the results of the same are exactly the same for both salt and fresh water planktonic investigations. Now the enumeration of 300,000 *Melosira* is obviously impossible, so for the enumeration of the more abundant individuals we have to make a second dilution. In the present instance we take from the 50 ccm. of the first volume, say 2·5 ccm., after the volume has been well shaken up in order that the organisms may become as evenly distributed as possible, and dilute this a second time until it becomes 50 ccm., then we have in this second dilution in every ccm. $\frac{300,000}{50 \times 2 \cdot 5} = 15,000$ *Melosira*. From this second dilution we count out the number of *Melosira* in one-tenth of a ccm., that is, 1,500. In this mass of water it is possible that we should not find any individuals of the rarer species, so that when we wished to count these, the dilution would not have to be carried so far, that is, 10 ccm. of the first dilution would be diluted up to 50 ccm. For the still rarer forms the first volume itself would have to be taken for the purpose of counting.

For the extraction from the diluted solution of an accurately known volume of liquid, Hensen has devised a form of apparatus known as the "Stempelpipette," that is a pipette furnished with a piston (see fig. 6). This instrument consists of a strong glass tube (*B*), the under surface of which is cut off quite evenly. This tube con-

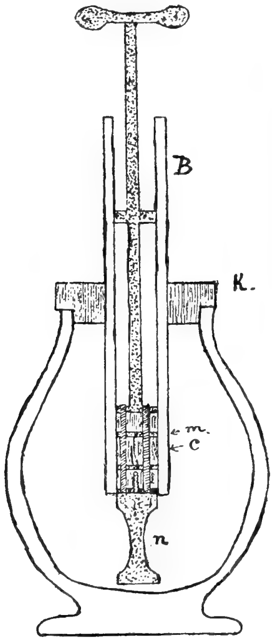

FIG. 6.

tains a moveable piston, consisting of alternating cork (*c*) and metal (*m*) plates, securely fastened together by two screws. To this piston a metal cylinder (*n*) is screwed, and this must exactly fit the glass tube. From this metal cylinder a quantity of metal is cut off so that between it and the glass tube an exactly known volume, say one ccm., remains. In order to do this, first of all a certain quantity of metal is cut away from the cylinder. The pipette is weighed. The cavity is then filled with mercury, and the pipette re-weighed. The weight of a ccm. of mercury is known, and more and more metal is cut away until the difference between the two weighings becomes equal to this. There are six such pipettes in common use, of capacities 0·1, 0·2, 0·5, 1, 2·5 and 5 ccm. These pipettes are passed through a strong cork (*k*), which is fitted into a glass vessel with strong walls. The fluid is poured into the latter vessel, and thoroughly shaken up, so that the plankton becomes evenly distributed throughout the whole volume, and as soon as this is the case the piston is pulled quickly up into the glass tube, so that the space (*n*) between the metal cylinder and the walls of the tube contains an exactly known volume of liquid. Before this fluid is subsequently emptied out it is as well to smear the under end of the glass tube with a little fat, as otherwise a drop of the fluid might easily hang there. After the volume has been ejected from the pipette, the latter is washed out with a little water, so that no organisms may remain behind. It is impossible to use the ordinary measuring pipettes in this connection, because the opening is so small as to become stopped up by some of the larger organisms.

If the dilution is sufficient for the immediate purpose, the counting may now commence, and for this a special form of microscope (fig. 7) has been devised. This microscope has a very large mechanical stage,* which is able to carry a glass plate of 11·5 by 10 cm., and this, by means of two screws, can be moved at will in either of two directions, from or to the observer, or sideways. This glass

* Mechanical stages are supplied by Zwickert, Optician, Kiel, and are made to fit suitable microscopes, from 60 marks upwards.

plate is engraved with fine lines cut in by means of a diamond, and each plate has a definite linear system. When the glass plate is in focus two parallel lines, in a direction perpendicular to the observer, are seen. When the side screw is turned successive lines are brought into the field of view. The rotation of the other screw gradually brings into view the whole of the space between

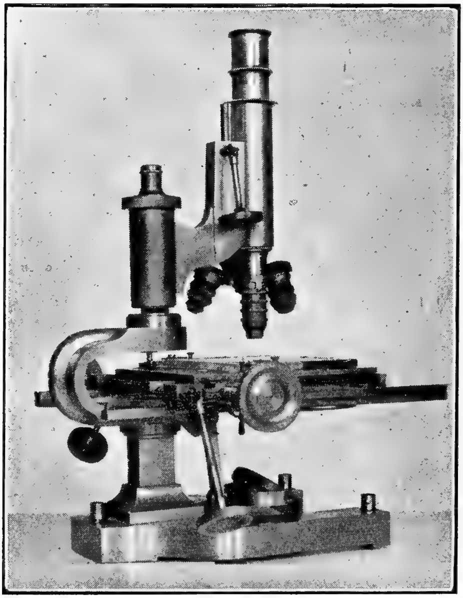

FIG. 7.

two given lines. The whole glass plate can thus, starting from one corner, be gradually brought into the field of view, and no part of it can possibly be overlooked. When a known volume of the diluted fluid is brought on to the glass plate the number of individual organisms of a given species can be readily determined, but the dilution is best arranged so that not more than one thousand and not less than one hundred of the organisms are found at one time on the glass plate. When the number of a single species only is enumerated at one time the counting is a simple matter, and is easily carried out. The plate is carefully looked over and every individual as it comes into the field of view is counted. In this way the total number of the individuals on the glass plate is arrived at, and the amount of the dilution being known the total number of individuals of that species in the catch can be calculated. Suppose, for example, the dilution to be ten times the original volume and that one ccm. of the diluted portion is used for the purpose of enumeration, and 55 *Clathrocystis* were found, then the total number in the catch of 50 ccm. would be $55 \times 10 \times 50$, that is, 27,500 individuals.

When it becomes necessary to count the different species of a genus, or a number of different species of plants or animals from the same plate, it is found expedient to adopt a labour-saving device suggested by Hensen. A box, divided into as many different compartments as there are species to be counted, and having each compartment labelled with the names of the species, is used for this purpose. The plate containing the various organisms is now brought under observation, and as each individual of a given species comes into view, the observer drops a token of some kind (button or coin) into the compartment labelled with the name of the species. In this way a plate with fifty different species can be easily investigated, The method is, of course, more practicable for the rarer individuals. The first organisms to be enumerated are usually the Diatomaceæ, as they are at certain seasons the most numerous constituents of the plankton. Firstly a strongly diluted portion of the catch is taken, and about one-tenth of a ccm. of the fluid is placed on the glass plate.

The magnification required for Diatoms and other small algæ is about 100. The amount of the fluid and the largeness of the magnification offer difficulties in the way of a successful counting. The amount of the fluid is so great that all the Diatoms in a given field of view will not be in focus together, so that it is found convenient to count the diatoms dry. The water is therefore evaporated by the plate being placed in the rays of the sun, or by being placed on the top of a paraffin bath, or any such suitable warm place.

On account of the mixing of the organisms and the diluted fluid not being quite uniform, different enumerations for the same species give different results from different plates, so that it becomes necessary to consider how many enumerations are requisite in order to give an average from which the total number of individuals in the whole catch may be accurately deduced. In general, it may be said that, for the species which occur most abundantly, when a fraction, say one-tenth of the square root has been counted it will be found sufficient to afford a basis for the calculation of the total number. For instance (see form, pp. 302-3) we might have on the first plate 43 examples of *Melosira*, and as we know that the fraction of the total volume taken for the purpose of calculation was one ten-thousandth part of the whole, the total number of *Melosira* would be, according to this single estimation, 430,000. The tenth part of the square root of this is 66. When at least 66 specimens of *Melosira* have been counted, we can regard the result as sufficient to supply us with an average, and no more need be counted. In order to find out the degree of correctness of the enumeration, Hensen adopted the following method:—An organism is first of all counted on several plates, and the average is taken. Then another plate is used, and this result, combined with the previous one, gives us a fresh average.

When this second average does not differ from the first by more than 5 per cent., the result may be taken to be satisfactory. In the form appended we find for *Melosira* the numbers 43, 38 and 48 on the first three plates. This gives us as average 43. The next counting gives us 38. The total now becomes 167 and the average 42.

Then it follows that $43 : 100 = 42 : x$.

$$x = 97{\cdot}7.$$

That is, the difference is 2·3 per cent., and therefore the counting can be regarded as accurate enough and completed, but of course it is always more advisable to use too many plates than too few. Having thus arrived at a sufficiently accurate result, we do not estimate the Diatoms on succeeding plates, and we can therefore use a weaker dilution and magnification. For the rarer forms the first dilution can be used, and from this 1 ccm. and finally 2·5 ccm., counted through; this work is much quicker, as a smaller magnification is used and only a few animals have to be counted. Each separate counting is noted on a form, an example of which is given (pp. 302-3). The forms originally used by Hensen are very complicated, and I have not attempted to produce one in its entirety; still the appended form is sufficient for all practical purposes. It may here be mentioned that the criticisms of Kofoid and the results obtained by Lohmann (9) seem to render some modification of the original form necessary. It seems useless to include organisms in the calculation the majority of which are proved to slip through the silk bolting cloth, No. 20. The forms are of two kinds. One is used for entering the results of an individual catch; the other for comparing such catches together. An example of the first only is appended. This

FORM FOR ENTERING RESULTS

No. 32A. Place—Dobersdorfer Lake. Date—20 ix., 1891. 14 ccm. diluted to 50.

Kind of investigation.	Amount of dilution.	No.	True volume.	Total.	Calculation.	Co-efficient.	Volume used.
wet. dry	2·5 : 50	1	0·005	...	50/0·005	10,000	0·1
,,	,,	2	,,	0·01	50/0·01	5,000	,,
,,	,,	3	,,	0·015	50/0·015	3,333	,,
wet	,,	4	,,	0·02	50/0·02	2,500	,,
,,	,,	5	0·025	0·045	50/0·045	1,111	0·5
,,	,,	6	,,	0·07	50/0·07	714	,,
,,	undiluted	7	0·1	0·17	50/0·17	294	0·1
,,	,,	8	,,	0·27	50/0·27	185	,,
,,	,,	9	,,	0·37	50/0·37	135	,,
,,	,,	10	0·5	0·87	50/0·87	57·4	0·5
,,	,,	11	,,	1·37	50/1·37	36·5	,,
,,	,,	12	,,	1·87	50/1·87	26·7	,,
,,	,,	13	1·0	2·87	50/2·87	17·4	1
,,	,,	14	Remainder	50	...	1	...

OF A SINGLE CATCH.

Under one square metre.	Total in catch.	Species.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	No. of plates.	Coeff.
86,851,314	573,276	Clathrocystis	55	60	57	?	...	...	...	...	...	...	...	...	...	...	172	1–3	3,333
9,089,091	59,994	Microcystis	6	6	6	?	...	...	...	...	...	...	...	...	...	...	18	,,	,,
12,331,494	81,396	Ceratium	10	10	3	11	54	56	?	...	...	...	...	...	...	...	144	1–6	714
65,138,486	429,957	Melosira	43	38	48	?	...	...	...	...	...	...	...	...	...	...	129	1–3	3,333
369,054	2,436	Copepoda larvæ	0	1	1	1	1	2	2	6	2	25	20	25	54	?	140	1–13	17·4
303	2	Cyclops ♂	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1–14	1
1364	9	Leptodora ♀	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	1–14	1
6818	45	Daphnia galeata	0	0	0	0	0	0	0	0	0	1	0	0	0	44	45	1–14	1
		etc.																	

form must be studied in connection with the explanation in the text. The form contains the results of one of Apstein's investigations (5) on the fresh water plankton of one of the Holstein lakes. Although the form records fresh water organisms, an exactly similar form can be, and is, used for salt water plankton.

The forms for comparing results of different catches present no special features, and one can easily be devised, so I have not thought it necessary to reproduce one here. At the head of such a form are printed the names of the various organisms captured in the plankton. At the left-hand side are spaces for entering the number and certain particulars regarding the catch. Underneath the heading for each organism and opposite the number of the catch are entered numbers giving the total number of organisms for the catch and the number per unit area of surface, so that it becomes easy to compare different catches either taken at the same place at different seasons or at different places.

With regard to the form, first of all in the top left-hand corner the number, place and date of the catch are noted. For instance, 32*a*. Dobersdorfer Lake. 20 Sept., 1891. The number 32*a* is recorded in a Journal in which information of a physical character is noted, such as the depth of water, its temperature, the temperature of the air, the direction and force of the wind, as well as the general condition of the catch, and any other information likely to be serviceable. On the form we see vertically and horizontally ruled spaces. Taking the vertical rows, we see on the extreme left the heading, "Kind of investigation." Under this heading we enter either dry or moist, according to the nature of the plate on which the enumeration is carried out. As a rule dry plates are only used for the enumeration of Diatoms. Under the second heading the amount of the dilution is recorded. 2·5 : 50 means that 2·5 ccm. of the original volume has been diluted with 47·5 ccm. of water, so that the total volume becomes 50 ccm. It is always better to dilute to either 100, 50 or 25 ccm., because flasks of these capacities can be easily obtained, the exact volume being indicated by a mark on the neck of the flask, and so any required dilution can be readily prepared for use. For the last plates, from 7 to 14, the original volume is taken, but from it only the larger species are enumerated. The next space is headed "number," and refers to the number of the glass plate used for the counting. As a rule ten plates are found sufficient. The form appended gives, however, fourteen. On the right of the form these successive numbers are used as head numbers. With reference to the "volume used," the numbers in this column signify exactly what volume of water has been used on each individual plate. For instance, on the first plate one-tenth of a ccm. was used, and this was from the dilution 2·5 : 50. This volume of liquid would be measured out by means of the "Stempelpipette" described above, and then brought on to the plate. As seen by reference to the form, several different volumes are used. Returning now to the rows on the left, we come to the heading "true volume." This differs from the volume used, and it gives us the proportion of the original volume that is actually investigated, whereas the volume used is the volume actually placed on the plate. The true volume is calculated as follows:—First of all 2·5 ccm. of the first dilution have been subsequently diluted to 50 ccm., and of this one-tenth of a ccm. has been taken. Now each of the 50 ccm. of the second dilution contains one-fiftieth of 2·5 ccm., that is 0·05 ccm. of the first dilution, and one-tenth of a ccm., the volume actually counted, contains

0·005 of the first dilution. On plate 6 we have used the same proportion of the first dilution, but we have taken half a centimetre for the purpose of counting, that is, five times as much as for plate 1, and consequently the true volume is 0·025 cm.

This true volume is important for the estimation of the coefficient. Under the heading "calculation" this is set out. Under the heading "true volume" for the first plate we get the number 0·005. The number of times that this is contained in the original volume (first dilution) is naturally 50/·005, that is, 10,000, so that one ten-thousandth part of the total number of organisms have been enumerated. For example, the number of *Melosira* reckoned for the first plate is 43. This multiplied by the coefficient 10,000, gives us the total number of *Melosira* in the catch, that is, 430,000. This number is of course approximate, and is corrected by the numbers obtained on the succeeding plates.

Suppose the individuals of a certain species have been counted on several plates, then it becomes necessary to determine the coefficient for the plates taken together (see heading "Coeff." on right-hand side of the table).

With this object the numbers given under the heading "true volume" for all the plates enumerated for a given organism are added together, and the coefficient is calculated exactly as described above for a single glass plate. For instance, for *Melosira* three plates in all have been counted, those numbered 1 to 3. The numbers respectively noted are 43, 38 and 48. Total 129. The sum of the true volume for the three plates is $3 \times \cdot005 = 0\cdot015$ ccm. Then the coefficient is 50/0·015, that is, 3,333. The total number of individuals counted, 129, is now multiplied by the coefficient, and that gives us the total number of *Melosira* in the whole catch, viz., 429,957.

We now consider the right-hand portion of the form. Under one heading the names of the species, the numbers of which it is desired to estimate, are entered. To the right of this are spaces in which the numbers of the glass plates are entered. When the enumeration of a given species is ended a query is placed in the column devoted to the next plate. When no individuals are found a cipher is naturally entered in the space provided. If, on the contrary, a given species is being investigated, but on certain plates not counted, a question mark is entered, and the plates are not considered in the summation. In the three last places on the right are entered the total number of individuals counted, the number of plates used in the enumeration, and thirdly the coefficient. Now, in order to find the total number of individuals of a given species in the catch, we have only to multiply the total number counted by the coefficient, as above indicated for *Melosira*. The number is then entered on the form in the space provided for the purpose.

The last heading to be considered is entitled "Under one square metre." We have seen from what has been written above in the description of the net that the whole volume of water, calculated from the area of the mouth of the net and the depth to which it is sunk, does not pass through the net, but part of it passes over the edge. It is therefore necessary to consider the filtration coefficient of the net, that is, what number the volume or number of organisms must be multiplied by in order to find the true value supposing the whole column of water filtered through. In the present instance the coefficient is 151·5, the estimation being made for one square metre surface area of the water column.

For *Leptodora* there are 9 females captured. In a column of water of one square metre section and 20 metres depth, therefore there would be $151 \cdot 5 \times 9$ such individuals, that is, 1,364.

In order to convey some idea of the laborious nature of this method of enumeration, it may be stated that Hensen himself says that he took a week, working eight hours a day, to count the organisms in a single catch. An important question here suggests itself. Is it likely that such an enormous expenditure of energy can be justified by the results obtained? A perusal of the results already obtained, a short summary of which is appended, is the best answer to the question. The obstacles in the way of a successful counting are numerous, but Hensen has attempted in a masterly manner to overcome them, and if one considers the success which has attended the solution of equally difficult problems, for instance, the enumeration of the corpuscles in the blood of man, there seems no reason to doubt that the Hensen planktonic method, if carefully employed, is a success.

All reckonings according to this method are so made that they can safely be regarded as minimum totals, and it is absolutely certain that in every case the fertility of the sea is really greater than indicated. Numerous control experiments have been made, and it is proved that with ordinary care the error never exceeds 20 per cent., and should on the average not exceed 7 or 8 per cent. These control experiments were partly so arranged that at the same spot several observations were made one after the other, the vertical net being in every case lowered to the same depth (comparative trials), or the same net would be successively lowered at the same spot to different depths (depth trials). The first series were useful to determine the errors likely to arise in an individual estimation. The second series served to prove that the plankton is evenly distributed in the upper layers of the water.

The quantitative plankton method has been used in the investigation of both fresh and salt water, and in the latter case both in the open ocean and in the neighbourhood of the coasts.

The following salt water areas have been investigated:

I.—Coastal areas. (*a*) For several years—Bay of Kiel

(*b*) During a whole year—

In the arctic seas. Karajak-Fiord, in N.W. Greenland, 70° N., by Vanhöffen.

In the Mediterranean. The Straits of Messina, by Lohmann.

In the Tropics. The Bay of Ralum, by Dahl.

(*c*) In the winter months—

The Gulf of Naples, by Schütt.

II.—Part of the open ocean, by means of a series of investigations carried out during a journey—

The west and other coasts of the East Baltic (to Memel and Gotland).

The north part of the North Sea from Skagen to the Hebrides.

A great part of the Atlantic Ocean during the Plankton Expedition (July-Nov., 1889).

The area between the Lofoten Islands and the north of Spitzbergen, during the Prince of Monaco's Expedition, in July and August, 1898.

Numerous investigations of fresh water lakes have also been undertaken, notably one by Apstein on the Lakes of Holstein.

Results.

As there are four methods of estimation, naturally the results may be conveniently grouped under four headings, namely, results of volume estimation, weight estimation, chemical analysis, and enumeration of the individual constituents.

The determination by volume has not been extensively employed, so we proceed to the consideration of weight estimation and chemical analysis, which had better be taken together.

Hensen (1) in his first work gives the results of fifteen weight determinations. Three of these were of the whole catch, which consisted mainly of Diatoms. Assuming that the masses of these catches were contained in a body of water of one square metre superficial area, and an average depth of 20 metres, we find under a square metre of surface in one case 1,608·3 ccm. of plankton, in another 2,723·5. The first mass contained 4·296 grams of dry organic substance, the second 6·128 grams. These results show very little dry organic substance, because the greater quantity of the catch consisted of Diatoms, which not only contain a large amount of water but on account of their hard shells contain relatively more mineral than organic substance. In 100 parts of dry substance, about 40 parts would be organic and 60 parts ash. The Peridineæ and Copepoda gave a much smaller quantity of water and a higher percentage of organic substance than the Diatoms. For the Peridineæ 100 parts of dry substance gave 96 parts organic to 4 parts ash. In the case of Copepoda the percentage of organic substance was 99. Fresh, consequently damp, Copepoda from the Baltic gave from 9 to 10 per cent. dry organic substance. The results are interesting, as they show the large amount of organic matter that the Copepoda contain, seeing that they form a large and important part of the food supply of fish. On the other hand, the Diatoms, in comparison with the other organisms of the plankton, contain a proportionately very small amount of dry organic substance, but they exist in such colossal quantities in the plankton that Hensen was able to demonstrate that by far the larger quantity of the organic substance of the plankton exists in the form of Diatoms.

The chemical analysis method has been further developed by Brandt (7), but it is more convenient to first of all consider Hensen's results deduced from the method by counting.

The most important results deduced from this method are in connection with the enumeration of the floating fish eggs. The first results were obtained in the West Baltic for cod and flat fish. The results of 120 such observations are detailed. These results are in some respects deficient, because the percentage of salt in the Baltic, and therefore the specific gravity of the water, varies greatly, so that occasionally the specific gravity of the water fell below the point at which it was possible for the eggs to float. The numbers must therefore be considered as minimal. Hensen concluded that for the Eckenförde waters, where the fishery for cod and flat fish is carried on (an area of about 16 square miles) there are in January an average of 30, in February from 45 to 50, in March at least 60, and in April 50, floating eggs of the above fishes per square metre of surface (with an average depth of 20 metres). These eggs take on the average 15 days to develop under the conditions obtaining in the West Baltic, so that the number above recorded must be doubled in order to give the number occurring per month under a square metre of surface water. This gives from January to April 370 eggs.

Hensen calculates that the number of cod and plaice annually caught by the Eckenförde fishermen would, if allowed to remain in the sea, have produced 23,400 million cod and 73,895 million plaice eggs annually. These figures are calculated from a nine-year average. These numbers give for every square metre of the 16 square miles of sea fished over 26·6 cod and 84 plaice eggs; total 110·6 eggs. This, added to the 370 calculated above, gives a total of 480·6, which represents the number of eggs that would have been produced from all cod and plaice, captured and free, yearly for each square metre surface water. As a consequence 110·6/480·6 = 1/4·4, gives the fraction of the total quantity of adult cod and plaice actually captured, or in other words, man captures for his own use every year about one-fourth of the total number of adult fish in this particular area of the West Baltic. This result is surprising to those who consider the resources of the sea as inexhaustible, and believe that the number of fish caught by man bears only a small proportion to the number actually present in the sea.

The estimation of the number of floating eggs according to this method has important practical bearings. For instance, it is possible to compare the fertility of a given area of the sea with this area of the West Baltic, and so to obtain an idea of the probable yearly catch of fish for that area. The results in the North Sea invariably gave a greater number of eggs per square centimetre than for the Baltic. On the other hand, results in the open ocean invariably gave less results than the Baltic.

As an exceptional instance, Hensen found on the 26th July, 1885, in the Skaggerrack 5,069 floating eggs per square metre of surface water; that is, for each square mile of surface water 278,795 million eggs. On this same journey, in the middle of the North Sea 230 eggs per square metre were found, on the Scottish side 275, and at another time 130 eggs per square metre.

The results of Hensen and Apstein for the North Sea in 1895 are of interest. Three journeys were made.

A	lasted	8	days, and	1,029	sea miles	were covered	(in Feb.),	and	49	catches made.
B	,,	9	,,	1,077	,,	,,	(in Feb. & Mar.)	,,	50	,,
C	,,	8	,,	1,291	,,	,,	(in April)	,,	59	,,

In the journey A the number of eggs and larvæ per square metre was 1,932, in B 6,538, in C 6,975; total 15,495 in 167 catches, eggs and larvæ being absent in nine catches. The average per square metre is therefore 92·5 eggs and young fish. This compares favourably with the Baltic average of 37·3. Estimating the surface area of the North Sea to be 547,623 million square metres, this gives a grand total for the North Sea of 148 million fish eggs and larvæ. After applying certain corrections and omitting Ammodytes' eggs and larvæ, as not being those of food fish, Hensen came to the conclusion that the North Sea during the year 1895 contained 157 billion eggs and larvæ. This number, being calculated from eggs and larvæ actually counted, must be regarded as too small.

Finally the Hensen method is of practical importance, inasmuch as it enables us to determine during which months of the year certain fish spawn. By means of this net Hensen, on one of his earlier Baltic expeditions, discovered that the sprat egg is, in contradistinction to that of the herring, pelagic. The spawning places and number of spawning individuals of the different species can also be approximately determined, since above them the floating eggs will be met with in the spawning season in large quantities.

With regard to the Copepoda, all the species are enumerated together. In addition, the larvæ and eggs (in the egg-sacks) were counted. For the West Baltic the number of Copepoda throughout the whole year is very similar, and is very high. The average number, inclusive of larvæ, for ten cubic metres of sea water, was on one occasion 725,900; on another 891,000. That is, a litre of West Baltic sea water contains from 72 to 89 of these little crustacea. The average depth of the West Baltic being 20 metres, there are present for every square mile of surface water from 80 to 100 billion Copepoda. The latter number gives a dry weight of 150,000 kilograms. The relation between adult Copepoda, larvæ and eggs was also determined. In a thousand specimens the average was 134 eggs, 461 larvæ, and 405 adults. The time required for the development of an adult Copepod is on the average a week. The birth-rate per week of the year for Copepoda is thus 134 per thousand. Assuming that the population of Copepoda remains fairly stationary, then the death-rate must be about the same. The calculation of the yearly mortality of the Copepoda of the Baltic becomes a simple matter. For 10 cubic metres of sea water, the mortality would be 175,000 per week, or in a year 8,866,500. Death to a Copepod generally implies that it is devoured by a fish or other animal. So that from a consideration of the death-rate of the Copepoda we can arrive at an idea of the food supply of some of our valuable marketable fish. The Clupeidæ feed largely on Copepoda. For a square mile of surface water the annual consumption of Copepoda can be regarded as approximately 975 billion, or for the 16 square miles of the Eckenförde fishery district a grand total of 15,600 billion. A billion Copepoda yield not less than 1,500 kilograms of dry organic substance, so that the 15,600 billion weigh not less than 23,400,000 kilograms. Taking the average weight of an adult West Baltic herring as being 60 grams, and allowing that every herring uses in 50 days its own weight of organic substance, we find that every herring consumes annually 438 grams. In the 16 square miles of the Eckenförde fishery district there exists food in the shape of Copepoda for 534 million herring of an average body weight of 60 grams. This result may of course be largely problematical, but it is at any rate extremely interesting. The North Sea, in a similar manner to the Baltic, contains an abundant wealth of Copepoda. The open ocean, on the other hand, contains much less.

The estimation of the number of free swimming larvæ of the larger edible crustacea, such as the crab and lobster, is also of practical interest, as on almost every coast a large number of the adult individuals may be met with. When applied to previously investigated coasts the method would yield results which would enable one to ascertain whether or not a fishery for such crustacea could be successfully established. The larvæ of the edible mollusca, the mussel, for example, are also frequently present in almost incredible quantities, and especially in the neighbourhood of coasts where the adults prevail. In the greater depths of the North Sea and in the open ocean such larvæ are rarely found.

On one occasion in the West Baltic it is calculated that in the case of the larvæ of *Mytilus edulis*, the number present was 170,000 for each square metre of surface water. If all these developed into adult animals, we should have for each square centimetre of bottom 17 adult mussels. This is, of course, physically impossible. It therefore follows that only an exceedingly small proportion of the larvæ ever become mature, the greater portion being devoured by other animals. It is thus seen that the larvæ of the various invertebrates play an important part in the food supply of other animals, particularly of young fish; but still they are not so important in this respect as are the Copepoda. In the first place, the number of invertebrate larvæ, Copepod larvæ being excepted, is never so large as the average number of Copepoda in a similar volume of water; and secondly, these larvæ are only present in enormous quantities at certain periods of the year, that is, when the spawning period of the adult occurs, and so belong to the "periodic plankton" in contradistinction to the Copepoda, which are always present, and therefore belong to the perpetual plankton.

The microscopic Infusoria, which are included under the title Tintinnæ, also belong to the periodic plankton. Their number is so enormous that they play an important role in the plankton. The principal Baltic form, *Tintinnus subulatus*, occurs to the number of 1,228,000 in 10 cubic metres of water. During the months when they are at a maximum their number equals that of the Copepoda, but as they are very much smaller, their total mass is much less.

The Peridineæ are also present in enormous quantities. The commonest form is *Ceratium tripos*, which is the usual cause of phosphorescence in the Baltic. The numbers for 10 cubic metres of water are, maximum 130 million, minimum 44,000, average 14 million. 130 million per ten cubic metres gives 13 for a cubic centimetre; the average gives 1·4 per ccm. The Peridineæ are of importance, since they presumably form the chief source of the food supply of the Copepoda. The food supply of the latter is not, however, definitely known. Hensen and other investigators found no determinable substance in their alimentary canal, but only a mass of green chlorophyll-containing material.

In order to determine whether or not the Copepoda lived on Peridineæ and Diatoms, Hensen made three experiments. The catch from a single net was divided into two parts. One part was immediately killed and preserved. The organisms in the other part were allowed to live for from 7 to 9 hours, and then killed and preserved. In each case the number of Diatoms and Peridineæ were in excess in the part that had been fixed and preserved immediately after capture. From this it is concluded that the Copepoda in the part allowed to stand for from 7 to 9 hours had devoured a certain number of Diatoms and Peridineæ. The number of consumed Peridineæ was in all cases in excess of the number of Diatoms consumed. From this it may be deduced with a fair amount of certainty that the Copepoda devour the Peridineæ. Probably the hard shells of the latter are not devoured, but are broken up by the complicated masticatory apparatus posessed by the Copepoda, and the edible contents extracted by means of the hair-like bristles.

Hensen endeavoured from the above experiments to determine the average number of Peridineæ annually devoured by a Copepod, and he concluded the number was 4,730. On the calculation that each square metre of surface water in the Baltic covers one million Copepoda, we see that 4,730 million Peridineæ are annually used up by these as food. A million Peridineæ yield 0·031245 grams of dry organic substance, so that the Copepoda of the Baltic use, per square metre of surface water, dry organic matter in the form of Peridineæ to the annual amount of 133·35 grammes.

The number and mass of Diatomaceæ probably exceeds all the other constituents of the plankton taken together. On account of their extraordinary minuteness, the capture and enumeration of these organisms is attended with no little difficulty. Two of the most important genera of the salt water Diatom flora are *Chætoceros* and *Rhizosolenia*, both with numerous species. They appear in enormous quantities in the Baltic, but do not seem to be present so abundantly at some seasons of the year, and the number also varies considerably in different years.

The species of *Chætoceros* attain their maximum in March, with an average of 457 million per cubic metre, or 457 in every ccm. of water. The principal species of *Rhizosolenia* that occur in the Baltic are *Rhizosolenia alata*, which reaches its maximum in May with a total of 85·7 per ccm., and *Rhizosolenia semispina* in March with an average of not less than 102·4 per ccm. Since a cubic centimetre of water contains on the average about 30 drops, it is no exaggeration to say that every drop of sea water in the Baltic is inhabited by Diatoms.

The North Sea, and especially the open ocean, contain very much smaller numbers of Diatoms than the Baltic. The Copepoda of the North Sea, on the other hand, show no diminution. In the North Sea, in spite of the much smaller quantity of the total catch than in the Baltic, the meshes of the net were much sooner obstructed, and the net itself took on a yellowish-green colour. Hensen concluded from this that there exists in the plankton still smaller unknown organisms which escaped through the meshes of the net. Subsequent research has shown this surmise to be justified. If the number of Diatoms in a drop of water is occasionally so high, what must be the case with regard to these still smaller organisms?

All animal life in the sea is ultimately dependent on vegetable life. This latter is in turn dependent on sunlight, and is therefore only able to exist down to depths to which the sun is able to penetrate, that is, a maximum of 400 metres from the surface. Thus by far the greater bulk of the ocean is unproductive of vegetable life, since it lies to a greater depth than 400 metres. It is certain that the Diatoms and Peridineæ play a far greater part in the cycle of matter in the sea than do the attached Algæ. The animals which inhabit the greater depths may be ultimately indebted to the spores of Diatoms and Peridineæ for their food supply, which spores are set free in enormous numbers, and contain, as it were, a concentrated extract of the organic substance of the plant. It is certain that Copepoda do not use Diatoms as food to any large extent, and it is as yet unknown what, if any, groups of animals habitually live on Diatoms, so that apparently the greater mass of the vegetable plankton is useless, at any rate directly, as a food for the animal part of the same. The Diatoms must consequently die and putrify, and it is known that the bottom of some of the shallower seas is covered by a large quantity of decomposing material. Behrens discovered that the percentage of combined nitrogen at the bottom of the sea varied from 0·18 to 0·4, which exceeds the percentage of the soil of the land considerably. The soil of the continents is likewise enriched by a large quantity of vegetable material, which is not directly used up by animals, but which is utilised by dispersion and decomposition.

Hensen has determined how much plankton is daily generated in the Baltic. The estimation bristled with difficulties, and the result must be considered as a minimum one. The conclusion arrived at was that for every square metre of surface water, omitting from consideration matter devoured by the animals of the plankton, there is daily generated at least 18 ccm. of plankton, giving for a year 6,570 ccm. This mass consisted principally of Diatoms, and according to the weight estimation method would contain from 14·8 to 17·7 grams of dry organic substance. The annual bill of fare of the plankton animals is calculated to be 133 grams for every square metre of surface water. Consequently the grand total of annual production of plankton per square metre of the Baltic is 150 grams, or for the whole sea $8\frac{1}{4}$ million kilograms. According to Biebahn and Rodewald, the produce of one square metre of cultivated land would be annually 179 grams. The fertility of the sea is thus seen to be on this reckoning about 20 per cent. below that of the land. But when it is taken into consideration that the estimation is based on "cultivated land," and when it is further considered what an enormous extent of land is incapable of cultivation, it will be seen that it is by no means improbable that the produce of the sea is really greater than the produce of the land. It seems however to be less favourable.

Detailed results of the method of investigation according to chemical analysis have been published by Brandt (8), and he has further instituted a most interesting and instructive comparison between the chemical constituents of the plankton, or single groups of plankton animals, and the land plants and edible fish and invertebrates.

For the three principal groups of organisms of the plankton Brandt gives the following results. All the figures are percentages:—

<table>
<tr><th colspan="3"></th><th>Chaetoceros and other Diatoms.</th><th>Ceratium and other Peridineæ.</th><th>Copepoda.</th></tr>
<tr><td rowspan="5">Organic substances.</td><td rowspan="2">Containing N.</td><td>albumen.</td><td>10</td><td>13</td><td>59</td></tr>
<tr><td>chitin.</td><td>—</td><td>—</td><td>4·7</td></tr>
<tr><td rowspan="3">free from N.</td><td>Fat.</td><td>2·8</td><td>1·3</td><td>7·7</td></tr>
<tr><td>sol. carbohydrates</td><td rowspan="2">22</td><td>39</td><td rowspan="2">20</td></tr>
<tr><td>cellulose.</td><td>41·5</td></tr>
<tr><td rowspan="3">Inorganic substances.</td><td colspan="2">Silica.</td><td>54·5</td><td>—</td><td>—</td></tr>
<tr><td colspan="2">Sea salt.</td><td rowspan="2">10·7</td><td rowspan="2">5·2</td><td rowspan="2">9·3</td></tr>
<tr><td colspan="2">Other ash.</td></tr>
</table>

A. Total Dry Weight.

	Diatoms.	Peridineæ.	Copepoda.
Albumen	28·7	13	65·1
Chitin	—	—	5·1
Fat	8·0	1·37	7·7
Carbohydrates	63·2	84·9	22·1

B. Dry Substance free from Ash.

Taking next the plankton as a whole, we find that the autumn and winter plankton of the Baltic takes a position intermediate between rich pasture and lupine.

	Albumen.		Fat.		Carbohydrates.		Ash.
Rich pasture	20·6	...	4·5	...	64.6	...	10·1
Autumn plankton	20·2–21·8	...	2·1–3·2	...	60–68·9	...	8·5–15·7
Lupine	20·6	...	2·6	...	72·0	...	4·6

The Peridineæ in chemical constitution are very peculiar, and differ markedly from the land plants used as fodder. The percentage of fat is very low, while that of carbohydrates, and especially of cellulose, is high. In both peculiarities the Peridineæ resemble good grass hay or rye straw.

	Albumen.	Fat.	Extracts free from N.	Cellulose.	Ash.
Rye Straw	3·5	1·5	38·8	51·3	4·7
Peridineæ	13·0	1·3	39	41·5	5·2
Good grass hay	13·6	3·2	48·2	26·8	8·2

On account of their comparatively large amount of albumen, the Peridineæ resemble the better kinds of fodder, but their small amount of fat and large amount of cellulose causes them to resemble the poorer sorts.

As spring approaches, a remarkable change is noticed in the plankton, the percentage of silica becoming very much higher, due to the sudden increase in the Diatoms.

In order to compare Diatoms with the land plants, the weight, free from ash, must be taken.

	Albumen.	Fat.	Carbohydrates.
Very good Lupine	29·3	2·8	67·8
Pea seeds	27·2	2·3	70·4
Diatoms	28·7	8·0	63·2

Compared with whole land plants, *i.e.*, excepting special parts such as rape seed, the percentage of fat in Diatoms is invariably found to be much higher. The albumen in Diatoms is also relatively high. On account of the high percentage of fat and albumen, as well as on account of the poverty of the carbohydrates, the Diatoms stand out in marked contrast to most of the land plants. The percentage of albumen in Diatoms is seen to be in excess of that in pea seeds. It must, however, not be forgotten that more than half of the Diatom total weight consists of silica, which possesses absolutely no nourishing properties. Brandt is of opinion that further investigations are necessary to determine the importance of Diatoms as a direct food supply of animals.

In the summer plankton the animal constituents come into prominence, so that it is no longer possible to compare the analyses with the land plants usually used as fodder. The albuminous constituents predominate. Fat is in one case low, in another case abnormally high, and the carbohydrates are comparatively very low. Other observations are necessary in order to determine whether the vegetable constituents of the plankton, invariably in summer, take a subordinate position as compared with the animals. It is very probable that the smaller chlorophyll-containing Flagellatæ, or even Schizophyte algæ, pass through the the meshes of the silk bolting cloth No. 20. The Copepoda form a very important food supply for fishes and other plankton-devouring animals. A comparison is instituted between the Copepoda and certain fish and edible Mollusca. The comparison is not so exact as for the plankton and land plants above, because in the case of the Copepoda and the mollusca the carbohydrates must be to some extent contained in the alimentary canal. In other respects, that is for albumen and fat, the Copepoda, oysters and mussels are comparable to the lobster and crab.

Dry Substance	Albumen.	Chitin.	Fat.	Carbohydrates.	Ash.
Herring.........	56·42	—	35·85	—	7·02
Salmon.........	60·49	—	35·62	—	3·89
Flounder	87·61	—	4·38	—	8·0
Cod	91·08	—	1·86	—	7·6
Lobster.........	79·80	—	10·13	0·16	9·41
Crab.............	78·87	—	7·69	3·75	9·6
Plankton Copepoda...	59	4·7	7	20	9·3
Oyster..........	46·8	—	9·5	28·1	16
Mussel	54·86	—	7·07	26·0	12

All the figures are percentages. The soft bodies only of the lobster, crab, oysters and mussels are included in the above table, the exoskeleton of chitin, or shell, being, as the case may be, omitted.

Brandt (7) has given a graphic representation of the chemical analysis of 11 plankton catches (fig. 8, p. 325).

A shows the volume of the catch after it has stood for 24 hours. *B* shows the dry weight of the same. In *C* the dry weight of the different constituents of the plankton are given. The Diatoms are represented by the clear spaces, the Peridineæ by the black, Copepoda obliquely lined, and the remaining organisms dotted. *D* gives the results of the chemical analysis, the dotted spaces represent the amount of albumen present, the black represents the fat, the horizontally lined the carbohydrates, the clear spaces the silica, and the obliquely striated the other ash. A glance at the figure shows how great an influence the Diatoms exert on the volume results as compared with the weight results. (Vide March, April and September, 1893). In spite of the enormous volume of the catch during these three months, the amount of dry organic substance remains small. In March, 1893, the volume has been graphically represented as three times as broad as the others, otherwise it would have had to be made three times as high.

The first three catches have a large quantity of *Ceratium*, and are therefore very rich in carbohydrates. The 6th and 7th catches are very rich in Diatoms, and hence contain a large quantity of ash, a fair amount of fat, and relatively little carbohydrate. The 10th catch, which in addition to a large number of Diatoms, contains also many *Ceratia*, is somewhat intermediate to the other catches. The plankton catches in summer (May and August, 1893) are seen to be made up in dry weight of

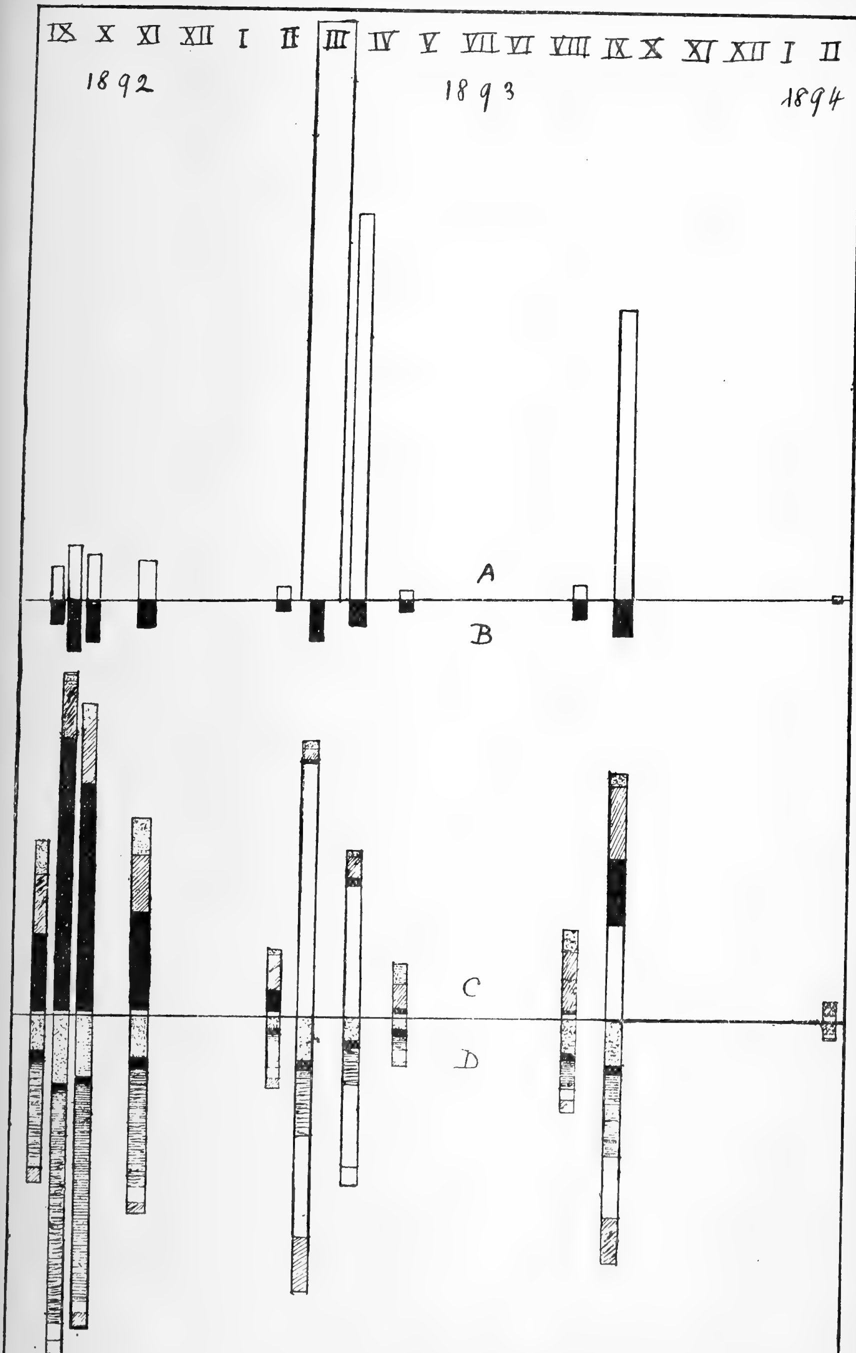
IX X XI XII I II III IV V VII VI VIII IX X XI XII I II
1892
1893
1894
A
B
C
D

Fig. 8.

from 60 to 70 per cent. of animals. One Copepod equals in dry weight 157 *Ceratium* individuals, or 1,500 *Chætoceros* cells.

In order to illustrate the distribution of the plankton during different months of the year, Brandt has drawn up annual curves for the years 1889 to 1893. The curves are based on the results of over 300 catches taken at a given spot, Buoy A, at the entrance to the Bay of Kiel, and at a depth of 20 metres. These catches were all made by means of the large Hensen plankton net. The curves are volume curves, based on volume measurements after the catch has been allowed to stand for 24 hours.

Very large catches are only made in the spring (fig. 9), from the middle of March or in April to the beginning of May. These maxima are due to the fact that at this time of the year the Diatoms multiply to an enormous extent, and this is especially true of *Chætoceros.* In the summer we get a second increase of Diatoms, namely, of *Rhizosolenia* species, so that in August or September a second maximum is established. The other catches show less marked peculiarities. The minima of plankton production occur in February or March, and again in May or June, that is, before and after the chief periods of increase of the Diatoms.

Although Hensen or Brandt made at least 70 observations at this spot, only on one occasion did they find so small a volume as usually occurs in the Sargasso Sea, and that was in February, 1894 (fig. 9). The Diatoms are so extraordinarily prolific that, in spite of their small size, they play an important part in modifying the plankton curves.

In conclusion, I may quote, as an example of the far reaching effect of plankton studies, from a highly interesting and suggestive work recently published by Brandt (9),

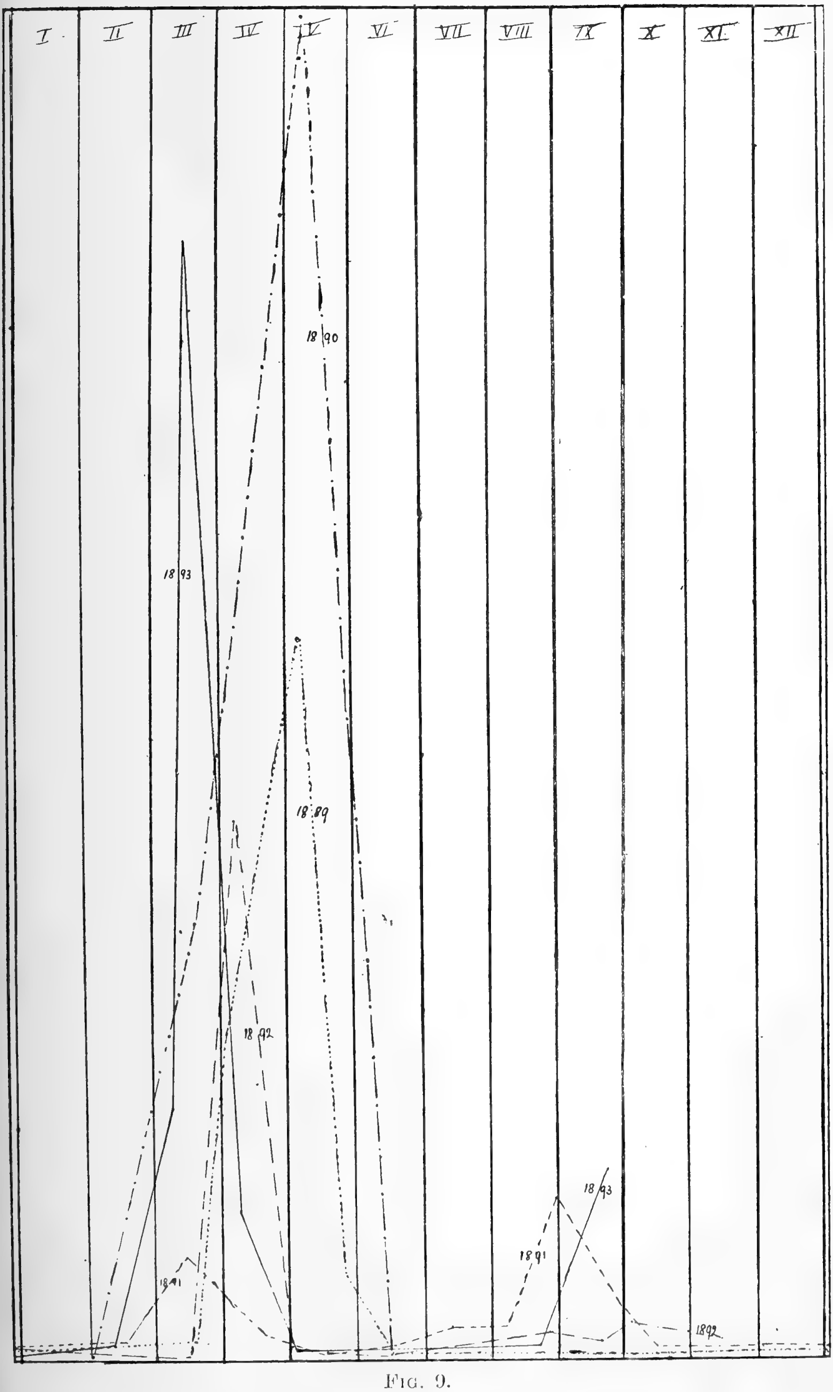
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
1890
1893
1889
1892
1891
1891
1893
1892

FIG. 9.

a few observations of the utmost importance both from a scientific and an economic point of view. Writing with reference to the circulation of matter in nature, he draws attention to the important part played by the denitrifying bacteria of the plankton. In nature the inorganic compounds containing nitrogen are present in three forms, as ammonia, as nitrates and nitrites. No plant can develop without inorganic nitrogen compounds, and as all animal life is dependent on plant life, it is seen that all life on the earth is ultimately dependent on the presence of these nitrogen compounds. It is therefore of importance to endeavour to trace their circulation. The three above-named nitrogen compounds and their combinations as well, are soluble in water. By the action of the atmospheric agents the nitrogen compounds of the land are gradually being washed out of the soil, and find their way by means of rivers to the sea. It is calculated that the Rhine alone carries over 130 thousand million grams of nitrogen every year into the sea, and the total amount annually conveyed by all rivers of the world is computed to be not less than 39 billion grams. But for the action of denitrifying bacteria the ocean would long since have become poisoned by the excess of nitrogen compounds.

These denitrifying bacteria, however, exercise a reducing action on the nitrogen compounds, so that nitrates are first of all reduced to nitrites, then to ammonia and lastly to free nitrogen. In this way the excess of nitrogen compounds in the ocean are destroyed. The identification of the different species of Bacteria that carry on the decomposition processes in the sea, the investigation of their mode of operation and their mode of life and their distribution in the sea is a subject of the greatest importance.

A study of the results already obtained by the German investigators leads to the following conclusions. In general the shallower waters are richer in plankton than the deeper seas, and of the latter the Sargasso Sea is exceptionally poor. In the shallower seas the influence of the bottom and of the solid land is quite appreciable. The plants have therefore in a smaller layer of water more food material, whereas in the deeper seas the inorganic nitrogen-containing food material is distributed over a very much larger volume of water, only the upper layers of which are capable of supporting plant life. The food material in the lower layers, which are devoid of sunlight, cannot be used up by plants. Apstein (5) divided the fresh water lakes of Holstein into two groups, *i.e.*, rich in plankton and poor in plankton. Brandt investigated the proportion of nitrates in the different lakes by means of the diphenylamine-sulphuric acid reaction (9, p. 228, footnote). The investigation of the lakes rich in plankton gave a result which showed them to be rich in nitrogen compounds; while the lakes poor in plankton were found on the contrary to contain but a small proportion of these compounds.

Another important result deduced from the quantitative plankton investigations is that the tropical and sub-tropical seas are comparatively poor in plankton, while the arctic seas are richer. On the dry land the contrary is the case with regard to the vegetable products. It would appear that the true cause of the wealth of the cold and the poverty of the warm seas in plankton is to be sought for in the different amount in which the denitrifying bacteria are present, and the influence which they exert on the presence of the nitrogen compounds in the water. If, as is apparently the case, a not inconsiderable denitrification takes place in the ocean, then it is probable that a destruction of the most important nitrogen-containing inorganic food supply of plants takes place to a greater extent in the warmer seas, since the activity of the bacteria in the lower temperatures of the arctic seas would not be so great as in the higher temperatures of the warmer seas, and consequently the same amount of destruction would not go on in the former case as in the latter.

As a practical bearing of this question, it may be asked whether the sewage deposited in or washed out to sea is, as is commonly supposed, wasted? The answer must be in the negative. The bacteria present in the sea water convert the sewage material into nitrates, nitrites and ammonia salts, which can be used up by the planktonic plants. These in turn are devoured by Copepoda and similar animals. These are then the prey of fish, which are in turn the food of man, himself ultimately destined for bacteria, and so the cycle perpetually runs its course.

About 19 million kilograms of nitrogen are yearly withdrawn from the North Sea in the shape of edible fish. This represents more than one-half of the nitrogen present in the North Sea at any given time. It is therefore obvious that the balance must be made up in the form of material derived from the land, and in this respect the sewage which annually drains into the North Sea cannot but be of importance, and hence must not be regarded as wasted.

Criticisms of the Hensen Method.

The Hensen method has been severely, and it seems to me, unfairly criticised by Haeckel.[1]

Haeckel particularly objects to the estimation of the adult fish from the number of floating eggs, but he has entirely misapprehended Hensen's point of view. Hensen

[1] Plankton Studien. Jena. G. Fischer. 1895.

endeavours to estimate the number of fish already present in the sea from the number of eggs produced by them, and not as Haeckel supposes, the number of fish those eggs will ultimately produce. In addition, Haeckel is of opinion that the plankton of the warmer seas is richer than that of the colder; but it must be remarked that his opinion—it is nothing more—is based on qualitative methods, whereas the methods of Hensen are based on quantitative experiments, carefully carried out, and their results have therefore a more sure and firmer foundation. Space does not allow me to enter into the discussion of these and other points raised by Haeckel. It is perhaps sufficient to say that his objections have been satisfactorily answered by Hensen[1] and Brandt.[2]

Kofoid[3] has recently published a criticism of the Hensen method. He employed the method in the investigation of the fresh water lakes in the district of Illinois, and he found that for the silk bolting cloth No. 20 the meshes were far too large and consequently most of the material slipped through, and his quantitative results were valueless. He further considers that the quantitative method of fishing with the plankton net is entirely impracticable, on account of the closure of the meshes by the captured organisms, so that the filtration capacity of the silk cloth and of the net itself varies in an uncontrollable manner. Therefore it is impossible to estimate what volume of water has been fished through, and the estimation of the volume or the number of the plankton constituents is in a like manner uncertain. On these grounds Kofoid wishes

[1] Die Plankton Expedition und Haeckel's Darwinismus. Kiel, 1891.

[2] Haeckel's Ansichten über die Plankton-Expedition. Schrift. d. Naturw. Vereins Schles-Holst. Bd.VIII. Heft 2. 1891.

[3] "On some important sources of error in the Plankton Method." Science, N. S., vol. 6, pp. 829-832.

to substitute pump and filter for the Hensen vertical net, which he considers useless.

It may be stated as a general proposition that no scientific method is perfect and incapable of being improved upon. Hensen himself is well aware of the defects of the method. With a view of confirming or rejecting the use of the net for such purposes as fish-egg enumeration and determination of the most important constituents of the plankton, for which it was primarily intended, Lohmann (10) has recently undertaken a number of observations on the Stollergrund (Baltic Sea), the results of which have just been published, and are of considerable interest and importance.

On the 8th November, 1899, Lohmann obtained 76 litres of water from the Stollergrund, and carefully filtered it, first of all through the silk bolting cloth No. 20, and subsequently through filter paper. The results were then tabulated, and the most important are here quoted. For plants, the auxospores of *Chætoceros* and small species of Naviculaceæ entirely escaped through the meshes of the net. Of small forms of *Coscinodiscus*, 98·6 per cent. in a like manner escaped. The percentage of forms in the case of the Diatomaceæ was almost invariably large, in the case of *Cocconeis, Nitschia*, and *Sceletonema costatum* being over 90 per cent. But of the most important Diatom, that is the largest form of Coscinodiscus (208μ), all specimens were retained by the silk cloth. Of the Peridineæ, 100 per cent. of *Dinophysis rotundata* and 98·7 per cent. of *Prorocentrum micans* escaped capture. Of *Ceratium tripos* var. *tergestina* and var. *baltica* 96·8 and 99·3 per cent. were respectively retained.

The whole of the specimens of *Peridinium divergens* were also retained as were the *Oscillaria* threads. Of the Tintinneæ, 97 per cent of *Tintinnus acuminatus* escaped, but of *Codonella campanula* the whole were retained. With regard to the eggs, only 19 per cent. of the egg sacs of the Copepoda were lost, eggs (of 81 μ diameter) with a shell, as well as eggs (127 μ diameter) with a soft membrane, were invariably retained.

With regard to the invertebrate larvæ, young larvæ, with a ciliated ring, invariably escaped capture. Of Copepod larvæ 14 per cent. escaped. With regard to the larger and more important animal constituents of the Plankton, a decided improvement is noticed. Of adult Copepoda only one-third per cent. (0·3) escaped capture, while *Evadne*, *Podon*, worm larvæ with long bristles, *Sagitta*, young mussels and gastropods, *Cyphonautes*, *Oikopleura*, and (?) *Planula* were invariably totally retained by the silk cloth.

It is thus seen that the individuals which escape play a small and insignificant part in the total volume or weight of the plankton, while the larger and more important individuals are invariably retained.

Kofoid's results, being based on observations made on fresh water plankton, are not directly comparable to the results obtained from the sea, since the nature of the plankton is in both cases very different, in the former consisting to a much greater extent of the very smallest Algæ and Protozoa.

The Latest Form of the Plankton Nets.

To meet the objections raised by Kofoid, which were in a measure substantiated by the experiments of Lohmann, Hensen (11) has devised two nets which will capture the smallest organisms in the plankton, and which are briefly described below. These nets, being protected externally by a strong metal covering can be used from a steamer which is travelling at a fair rate of speed.

The first of these nets is the basket net ("Korbnetz"), so-called because the protective covering was originally of basket work. This has now been dispensed with, and a strong metal covering has been substituted. This net is shown in section (fig. 10). *A* is a strong metal covering

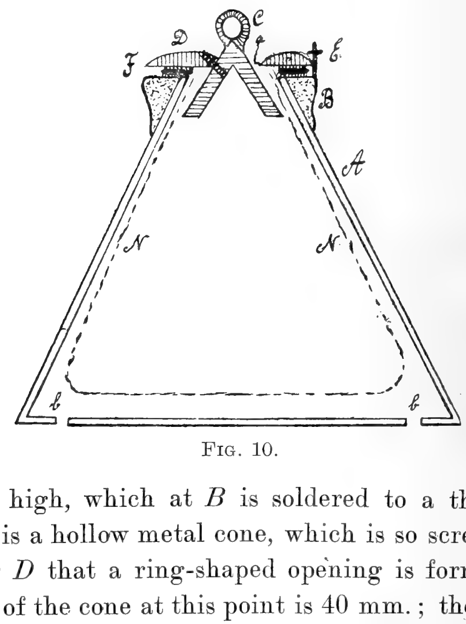

FIG. 10.

240 mm. high, which at *B* is soldered to a thick metal ring. *C* is a hollow metal cone, which is so screwed on to the cover *D* that a ring-shaped opening is formed. The diameter of the cone at this point is 40 mm.; the diameter of the outer edge of the ring-shaped opening is 48 mm. The whole cover is fastened on to the metal conical covering by means of three overfall screws, one of which is represented at *E*. The cover *D* rests on a ring *F* which is covered with fustian, and to which the net (*N*) itself is sewn. When in use the net expands, because in the under surface of the metal cone there are two small apertures of a total area of 5·5 square centimetres. Through these openings the water escapes, and so the expansion of the net is brought about.

The net is let overboard over the stern of the ship while still in motion, with sufficient rope to allow it to remain under but near to the surface. It is allowed to remain out for ten minutes or a little longer, then hauled in and the plankton emptied into a glass trough. If the net is allowed to remain out too long, it becomes so blocked up with plankton that it filters badly. In this way the pressure on the net becomes considerably increased, and it is liable to become ruptured. When used during the above-mentioned time the Appendicularia are captured uninjured and alive. If the catch is very slimy, the net gets stopped up sooner than usual. Although Hensen described the construction of this net, and its mode of use, fourteen years ago, nets of similar character have been described by other investigators. Borgert has described a modification which differs from the Hensen "Korbnetz" in that it is quite free behind. Hensen considers that the strain on the net in that case would be too great, and that the net would be easily torn, but Borgert has not found such to be the case. The calculation of the volume of water which passes through this net in a particular instance is complicated, and depends on a number of variable factors, among which are the area of the opening, the length of time the net is out, the speed of the steamer, the angles formed by the rope attached to the net, to the perpendicular, when being let out and when being pulled along. This net serves admirably for the capture of plankton from a steamer when going at full speed.

The latest form of quantitative plankton net, and one which, like the Korbnetz, is capable of being used from a steamer going at full speed, is one devised by Petersen and improved by Hensen, here designated as the Petersen-Hensen net (fig. 11). This net combines a strong protective covering, with an aperture of the smallest possible dimensions and a filtering surface of very large area. The cubical capacity of the net is also as small as possible, so that when it is hauled up it is unnecessary to wait so long for the water which remains in it to filter through. It is also easy to unfold the net, to wash out its contents, and replace it in the metal covering. In order to increase the surface of a net either its length or its circumference can be increased. Hensen at first tried pushing in the net on itself, in a similar manner to that in which the finger

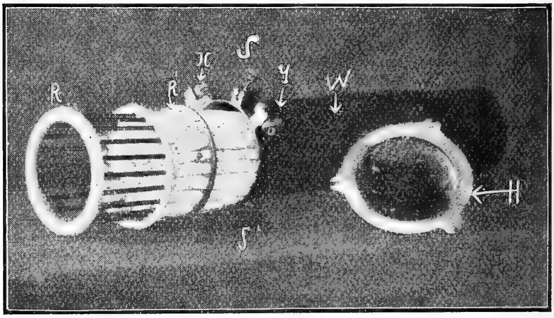

Fig. 11.

of a glove can be pushed in. This form was given up because the net was inconveniently long and the end very narrow. The case might be made square and the surface increased by deep foldings, so that the surface resembles a photographic camera. This form would be very convenient and practicable if the net could always be arranged in such folds. A spiral arrangement of the net appears impracticable, therefore the net has been folded in the direction of its longitudinal axis, as was done by Hensen for his cylinder net (4, p. 111), but with the modification that the net lies in a basis that can be fully withdrawn from the metal covering.

There are two rows of metal rods, which serve to keep the net in place. The inner row, not visible in Fig. 11, is attached to the lower metal ring *R′*. This row of rods is external to the net. The outer row attached to the ring *R* is inside the net, and serves to keep its folds in position. When the headpiece, *H*, is taken off from the metal covering, *W*, it is possible to remove the upper ring *R* with the attached rods, which lie, as has been noted above, outside the net. The net itself can be subsequently removed, inverted, its contents washed out, and it can then be replaced in the metal covering.

Attached to the upper end of this covering are three metal rings. To the ring *X* a weight of about half-a-hundredweight is attached, the use of which is indicated below. To the ring *Y*, and to a similar ring 180° away from it, ropes are attached which allow of the net being let out and hauled in. The cover is fastened to the cylinder by means of three overfall screws, two of which, *S* and *S′*, are shown in the figure.

In the cover *H* of the cylinder there is a turbine to which an indicator is attached, by means of which the volume of the inflowing water can be estimated. The turbine is mounted on an axis provided with stones, the points on which the turbine rotates are of Iridium-platinum. Iron is useless for the purpose, as it so soon becomes rusty. It does not much matter if a little water flows into the net near the turbine, that is, where the turbine rotates, but it is better to avoid this loss. In the tube of the turbine there is, therefore, a sharp cutter which prevents this, and also serves to cut to pieces any organisms that might lodge there, and prevent the rotation of the turbine. On the axis of the turbine an indicator is placed. This measures up to 15,000 revolutions. When the turbine has revolved 1,400 times about 500 litres of water have passed through. The turbine gives relatively true volumes of water when used at fairly similar velocities. The absolute volume may be estimated if the head piece be placed in water and through the opening a measured volume of water be poured. The amount for one rotation is 0·44 litre.

The net is so manipulated that it cannot quite sink to the bottom. The use of the weight mentioned above obviates this. The weight itself sinks to the bottom, and if it be allowed to remain there the net itself cannot sink so far. It is possible to estimate when the weight touches the bottom by trying with the rope or by greasing the weight, and making several trials for the depth. The haul is a diagonal one, and its length may be calculated if the following factors are known:—the velocity with which the net sinks, the distance the ship has travelled from the point where the weight touched bottom, and the angle between the rope attached to the net and the vertical.

A number of drawbacks stand in the way of the exactitude of a quantitative estimation of all the organisms which are retained (usually) in the net. These are—

1. The ship frequently does not remain in the same situation, and undercurrents influence the net, so that possibly more of the upper layers is fished through at one time than another.

2. The variability of the pull on the net is in marine investigations uncontrollable.

3. It happens on account of the length of time the net remains damp, and the subsequent drying in the sun, that a shrinkage is set up. This happens earlier when the net is mishandled, but is sooner or later unavoidable.

4. Owing to the organisms becoming embedded in the pores of the net and to the drying of slime on it, it becomes ultimately permanently stopped up.

Practical Applications of the Hensen Method.

It cannot be denied that the application of this method has yielded valuable and important results, in the shape of additions to our knowledge of the conditions of life in the sea, and more particularly that portion of the life which comes under the heading of plankton. In this way a great step forward has been made. The plankton undoubtedly forms the sole food supply of many of our most important food fishes, for example, the herring, sprat and mackerel. For the solution of the problem of the migration of the herring we must probably seek further in this direction, as it is in all likelihood connected with the variation in their food supply, that is, in the variation of the plankton, or more particularly the variation in the Copepod constituents of the same. In like manner the estimation of the number of floating fish eggs in the sea gives us an idea of the total number of spawning fishes present at that time in the portion of the sea investigated.

The quantitative method thus started for plankton work might be capable of extension in other directions. It might be possible to estimate how much valuable human food in the shape of fish is annually consumed by porpoises and dogfish around our coast. These destroyers of fish are undoubtedly our most formidable competitors, and should be ruthlessly destroyed. Another animal which might be quantitatively investigated is the starfish. The amount of damage done by this pest in the way of destruction of mussel, oyster and other shell fish beds might be estimated. Hensen has suggested a method for converting star fish into manure.

While the present paper was in the press, there appeared the preliminary announcement of a work on Plankton Methods, by Volk,[1] who has investigated the Plankton of the Elbe and its tributaries and the harbour at Hamburg. He found that he obtained no exact results by the Hensen-Apstein method, though no reason is given for the supposed inexactitude. He therefore suggests a new method, which consists in the employment of a rotary pump, with a contrivance for pumping up water from different layers. To the pump is attached an apparatus by means of which the volume of water can be measured, and the depth to which the lower opening of the pump is sunk can also be ascertained. The water is first of all filtered through an Apstein net, the meshes of which are however not small enough to capture the smaller organisms. The water is therefore subsequently mixed with formalin, and carefully filtered. For the purpose of filtration either porcelain, burnt clay, silica or charcoal may be used. The organisms were, for the purpose of quantitative estimation, shaken up in a viscous fluid consisting largely of formalin, and a given portion of the fluid was weighed out on to a glass plate and the organisms counted. Volk says that he has such solutions which after 10 months' standing have no deposit.

[1] Zur Plankton-Methodik (Vorläufige Mittheilung). Zool. Anz. 1901. p. 278.

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2. FR. HEINCKE, Die Untersuchungen von Hensen über die Produktion des Meeres an belebter Substanz. Deutscher Fisch. Ver. Nr. 3. 4. 5. März, April, Mai, 1889.

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9. BRANDT, Ueber den Stoffwechsel im Meere. Wissensch. Meeresuntersuch. N. F. Bd. 4. Kiel, 1899.

10. LOHMANN, Ueber das Fischen mit Netzen aus Müllergaze Nr 20 zu dem Zwecke quantitativer Untersuchungen des Auftriebs, Wissensch. Meeresuntersuch. N. F. Bd. 5. Heft 2. Kiel, 1901.

11. V. HENSEN, Ueber die quantitative Bestimmung der kleineren Planktonorganismen und über den Diagonal—Zug mittelst geeigneter Netzformen. Wissenschaft. Meeresuntersuch. N. F. Bd. 5. Heft 2. Kiel, 1901.

SOME ADDITIONS to the FAUNA of LIVERPOOL BAY,

Collected May 1st, 1900, to April 30th, 1901.

By Andrew Scott.

[Read May 10th, 1901.]

Since the publication of the paper by I. C. Thompson, F.L.S., and myself in the Transactions of the Society for last year,* further additions to the published lists have turned up. The new records, chiefly Crustacea, were found while carrying on various investigations connected with fisheries work in the Piel Laboratory, partly during the past year and earlier portion of the present one.

This report represents an addition of thirty species not previously recorded for the district. All of these have come under my own observation. The additions include, one sporozoan fish parasite, six worm parasites of fishes, and twenty-two crustaceans, represented by one Macrurid, two Sympoda, one Branchiurid, four Ostracoda, and fourteen Copepoda. Of the Copepoda, only two are non-parasitic; the other twelve are parasites on various fishes. The latter include one new species and another for which a new genus is now established. A number of the additions are here recorded for the first time from the sea round the English coasts.

* Some Recent Additions to the Fauna of Liverpool Bay. Trans. L'pool Biol. Soc., vol. xiv., 1900, p. 139.

PROTOZOA.

1.—*Glugea lophii*, Doflein.†

Glugea lophii, Mrázek, Sporozoenstudien II. Sitz. d. Konigl. Böhmischen Gesellschaft d. Wissenschaften. Mathematisch-naturwissenschaftliche classe (1899).

The cysts of this protozoan were found imbedded in the posterior region of the brain of the Angler fish (*Lophius piscatorius*) forming a conspicuous mass, easily visible to the naked eye when the brain had been dissected out. Very much larger masses of cysts were found surrounding the main trunks of the seventh nerve just outside the skull. The fish measured about two feet in length, and was caught on the offshore station between Lancashire and the Isle-of-Man, April 19th, 1901. Mrázek obtained his specimens from *Lophius* caught at Triest and Naples.

VERMES (*Trematoda*).

2.—**Dactylocotyle pollachii*, Van Beneden and Hesse.

Dactylocotyle pollachii, Van Beneden and Hesse, Recherches sur les Trématodes, p. 110, pl. xi., figs. 23-30 (1863).

Attached to the gills of Pollack (*Gadus pollachius*) caught on the offshore stations between Lancashire and Isle-of-Man, March 13th and April 19th, 1901.

3.—*Octobothrium merlangi* (Kuhn).

Octostoma merlangi, Kuhn, Mém. Mus. d'hist. nat., vol. xviii. (1830.)

Attached to the gills of Whiting (*Gadus merlangus*) from the offshore stations between Lancashire and Isle-of-Man, March 13th, 1901. This species has been recorded from the Firth of Forth, by Mr. T. Scott, F.L.S., in Thirteenth Annual Report, Fishery Board of Scotland (Part III.).

† J. Doflein, Studien zur Naturgeschichte des Protozoen: III. Ueber die Myxosporidien Zool. Jahrb. Bd. xi. (1898.)

4.—**Octobothrium scombri* (Kuhn).

Octostoma scombri, Kuhn, Mém. Mus. d'hist. nat., vol. xviii. (1830).

Attached to the gills of Mackerel caught off the Manx coast, August, 1900. This is a very slender species and unless the gills are carefully examined will be easily overlooked.

5:—**Onchocotyle appendiculata* (Kuhn).

Polystoma appendiculatum, Kuhn, Mém. Mus. d'hist. nat. vol. xviii., p. 362 (1830).

Attached to the gills of Grey Skate (*Raia batis*), caught on the offshore stations between Lancashire and Isle-of-Man, February, 1900. It is easily identified by having, in addition to the six suckers at the posterior end, a slender median appendage arising from between the suckers and passing in an anterior direction.

6.—**Phyllonella soleæ*, Van Beneden and Hesse.

Phyllonella soleæ, Van Beneden and Hesse, Recherches sur les Trématodes, p. 70, pl. v., figs. 1-8 (1863).

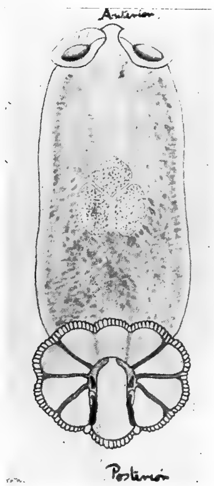
Attached to the scales on the "white side" of the Common Sole (*Solea vulgaris*), caught on the offshore stations between Lancashire and Isle-of-Man, April 19th 1901.

7.—? *Placunella pini*, Van Beneden and Hesse.

Placunella pini, Van Beneden and Hesse, Recherches sur les Trématodes, p. 72, pl. v., figs. 9-18 (1863).

Attached to the gills of Yellow Gurnard (*Trigla hirundo*), caught on the offshore stations between Lancashire and Isle-of-Man, April 19th, 1901.

This species differs in some respects from the figure of *Placunella pini* given by Van Beneden and Hesse, as will be seen from the appended drawing, and may turn out to be a different species. There are eight distinct and two indistinct rays in the large posterior sucker. Van Beneden and Hesse (op. cit.) give a description with figures of *Trochopus tubiporus* (Diesing) from the Yellow Gurnard, but the above species does not appear to be that form.



? *Placunella pini*, Van Beneden and Hesse, from ventral surface. × 16.

There is no doubt that by careful examination of the various fishes taken in the local sea, other trematode parasites will in time be found. Practically every species of fish has its own peculiar parasites, but some are more easily overlooked than others on account of their small size and resemblance to the particular region they adhere to.

Crustacea (*Macrura*).

8.—*Upogebia deltäura* (Leach).

Gebia deltäura, Leach, Malac. Podolph. Brit., t. xxxi., fig. 9, 10.

An almost perfect specimen of this curious lobster-like crustacean, measuring two inches in length, was found in the stomach of a haddock caught on the offshore station between Lancashire and Isle-of-Man, March 13th, 1901.

The *Upogebia* had evidently just been swallowed by the fish, as it was perfectly fresh, and the gastric juices had not had time to act upon the carapace. It belongs to the Callianassidæ, a family of Crustacea which burrow under the surface of the sea bottom, and as Rev. T. R. R. Stebbing remarks, "are more often obtained from the stomachs of fishes than by intentional methods of capture."

There is some doubt whether this species is really distinct from *Upogebia stellata* (Montagu), but the present form, which has the inner branches of the uropods deltoid in shape, agrees better with the species described by Leach than with Montagu's *U. stellata.*

Sympoda.

The Rev. T. R. R. Stebbing in his memoir on some crustacea from the South Seas collected by Dr. Willey (Willey's Zool. Results, part V., 1900), has shown that *Cuma*, so familiar as the name of a genus of Crustaceans, is preoccupied; and as the subordinal name *Cumacea* is derived from *Cuma* and must also lapse, he adopts the name *Sympoda* for this sub-order instead of *Cumacea.*

9.—*Eudorellopsis deformis* (Kröyer).

Leucon deformis, Kr., Nat. Tidsskr, vol. 2 (2nd series), p. 194, pl. 4 (1846).

This peculiar little form, though probably widely distributed, is apparently rare. Only one specimen has so far been found in the Irish Sea. It is easily recognised, when mixed with *Eudorella,* by the turned up rostrum.

In bottom material collected N.W. of Bahama Lightship, off the north end of the Isle-of-Man.

10.—*Pseudocuma similis*, G. O. Sars.

Pseudocuma similis, G. O. Sars., Crustacea of Norway, vol. iii. (Cumacea), p 76, pl. 53 (1900).

It is probable that this Cumacean has been passed over as a deep-water form of *Pseudocuma cercaria* (Van Beneden), which is occasionally met with in the sandy bays round the Lancashire coast. Professor G. O. Sars, in his work on the Crustacea of Norway, now separates it from that species, and shows its distinguishing characters. One of these is the presence of three small but quite distinct teeth at the anterio-lateral angles of the carapace.

In the same gathering as the last. Two specimens were found.

OSTRACODA.

11.—*Cythere pellucida*, Baird.

Cythere pellucida, Baird, British Entomostraca, p. 173, pl. xxi. fig. 7 (1849).

This form is very abundant, especially during the summer months on the muddy sand flats along the coast.

Common on the mud flats near Piel, practically throughout the year.

12.—*Cythere porcellanea*, Brady.

Cythere porcellanea, Brady, Ann. and Mag. Nat. Hist., ser. iv., vol iii., p. 47, pl. vii., figs. 1-4.

Usually associated with *C. pellucida*. Some care has to be taken in identifying the two forms owing to the amount of variation that occurs amongst the two species.

In the same locality as the last. August, 1900.

13.—*Cythere gibbosa*, Brady and Robertson.

Cythere gibbosa, B. and R., Ann. and Mag. Nat. Hist., ser. iv. vol. iii., p. 368, pl. xxi., figs. 1-3.

This ostracod is frequently found in gatherings from the mud flats left dry by the receding tide associated with *C. pellucida* and *C. porcellanea*, but is easily distinguished from either of these species.

In tidal pools near Piel. August, 1900.

14.—*Cytheropteron humile*, Brady and Norman.

Cytheropteron humile, B. and N., Monog. of the Marine and F. W. Ostracoda. Trans. Roy. Dublin Soc., vol. iv., ser. ii., p. 219, pl. xx., figs. 4-7 (1889).

Many specimens of this remarkable little ostracod were found by washing waterlogged and decayed wood in weak spirit, and examining the sediment. This appears to be the true habitat of the species. My father, who first found the species in material dredged in the Clyde, tells me that he always finds it when examining the sediment washed from old wood brought up in the trawl net, and remarks that it seems to be partial to that kind of habitat.

In waterlogged wood burrowed by wood-boring crustacea, collected between tide marks in Barrow Channel, near Piel, April 18th, 1901.

Branchiura.

15.—*Argulus foliaceus* (Linn).

Monoculus foliaceus, Linn. Syst. Nat., edit. 10th, 1,643, No. 2 (1758).

On Trout from the Ribble, which were sent to University College, Liverpool, for examination. June, 1900.

Copepoda (Free).

16.—*Stephus gyrans* (Giesbrecht).

Mobianus gyrans, Giesb. Pelagischen Copepoden des Golfes von Neapel (1893).

Amongst material collected in *Laminaria* bed, near Piel, at a very low ebb. August, 1900.

17.—*Idya minor*, T. and A. Scott.

Idya minor, T. and A. Scott, Annals of Scottish Natural History Oct., 1896.

In the same material as the last species.

Copepoda (Parasitic).

18.—*Bomolochus soleæ*, Claus.

Bomolochus soleæ, Claus, Zeitschrift fur Wissenschaft Zool. vol. xiv., p. 374.

A number of specimens of this Copepod can usually be found by pressing the nostrils of Cod, so that mucus, &c., may be ejected. The mucus is then placed in a drop of water, and the copepods, if present, are easily seen. The females have two large white egg sacs.

From small cod caught in Barrow Channel, August, 1900; and also in the nostrils of large cod caught on the offshore fishing grounds between Lancashire and Isle-of-Man, March, 1901.

19.—*Caligus minimus*, Otto. Pl. 1, figs. 1-8.

Caligus minimus, Otto, Beschreibung neuer Crustacean, p. 354, pl. xxii. 1828.

This is a well marked species, and may easily be distinguished from other Caligi by the long slender antennules and large caudal stylets. The second foot-jaws in the male are powerful grasping appendages.

Frequent in the mouth of the Bass (*Labrax lupus*), caught in Barrow Channel, August, 1900.

Length of female, 4·9 mm.; male, 6·9 mm. It is rather unusual to find the males of copepod fish parasites larger than the females.

20.—*Caligus brevicaudatus*, n.sp. Pl. II., figs. 7-10.

Length of female, 5·3 mm. The characters which distinguish this species from the other members of the genus are, 1° the extremely short abdomen and caudal stylets; 2° the fourth pair of feet, the expodite of which is very slender.

Inside the mouth of the Common Gurnard (*Trigla gurnardus*) caught in the vicinity of Piel, August, 1901.

Pseudocaligus, nov. gen.

Animal similar to *Caligus*. The general structure of the various appendages, with the exception of the fourth pair of feet, is the same as in that genus. Fourth pair of feet very rudimentary, almost obsolete, consisting of a basal portion only; no exopodite, as in *Caligus*.

21.—*Pseudocaligus brevipedes* (Basset Smith). Pl. II., figs. 1-6.

Caligus brevipedes, B. Smith, Ann. and Mag. Nat. Hist. (6), vol. xviii., p. 11, pl. iii., fig. 1 (1896).

A number of specimens of this species were found inside the operculum of a three-bearded Rockling (*Onus tricirratus*), caught in Barrow Channel, August, 1900. Also on another one sent me by Mr. Chadwick, Port Erin, March, 1901.

Length of female, 3·6 mm.; male, 2·8 mm.

22.—*Lepeophtheirus pollachii*, Basset Smith.

Lepeoptheirus pollachii, B. Smith, Ann. and Mag. Nat. Hist. (6), vol. xviii., p. 12, pl. iv., fig. 1 (1896).

Attached to the inside of the mouth of Pollack (*Gadus pollachius*), caught on the offshore stations between Lancashire and Isle-of-Man, March, 1900, March and April, 1901.

23.—*Cycnus pallidus* (Van Beneden).

Congericola pallidus, Van Ben., Bull. Acad. Roy. Belg., vol. xxi. pl. 11 (1854).

On the gills of the Conger (*Conger vulgaris*), caught in the Barrow Channel, March, 1900; also on Congers from the offshore stations, caught at various times during the past two years. A number of specimens were found on each fish examined. It is a small, slender species, and easily overlooked.

24.—*Oralien asellinus* (Linn).

Lernæa asellina, Linn. Fauna Suec., 2101 (1761).

On the gills of a Yellow Gurnard (*Trigla hirundo*) from the offshore station between Lancashire and Isle-of-Man, April 19th, 1901. This appears to be a very variable species, and the figures given by various writers on fish parasites all show differences, more or less marked. The species, therefore, requires further study, as it is possible that there is more than one *Oralien*.

25.—*Chondracanthus cornutus* (Muller).

Lernæa cornuta, Muller, Zool. Dan., vol. i. (1776).

On the gills of Plaice (*Pleuronectes platessa*) from the offshore station between Lancashire and Isle-of-Man, March, 1900. What appears to be a variety of this species occurs on the gills of the Flounder (*P. flesus*) from the Barrow Channel and other parts of the Lancashire coast.

26.—*Chondracanthus clavatus*, Basset Smith.

Chondracanthus clavatus, B. Smith, Ann. and Mag. Nat. Hist. (6), vol. xviii., p. 13 (1896).

On the gills of Lemon Soles (*Pleuronectes microcephalus*) from the offshore station between Lancashire and Isle-of-Man, February, 1900, and also from Barrow Channel.

27.—*Chondracanthus soleæ*, Kröyer.

Chondracanthus solæa, Kr., Naturh. Tidsskr. I., p. 139 (1838).

On the gills of the Common Sole (*Solea vulgaris*) from the offshore station between Lancashire and Isle-of-Man, April 19th, 1901.

28.—*Charopinus dalmannii* (Retzius).

Lernæa dalmannii, Retz. Froriep's Notizen, vol. xxix. (1831).

In the spiracles of the Grey Skate (*Raia batis*) from the offshore station between Lancashire and Isle-of-Man, February, 1900.

30.—**Brachiella insidiosa*, Heller.

Brachiella insidiosa, Heller, Reise der Novara, p. 239 (1865).

On the gills of the Hake (*Merluccius vulgaris*) from the vicinity of Calf of Man, 1900.

30.—**Brachiella ovalis*, Kröyer.

Anchorella ovalis, Kröyer, Naturh. Tidsskr., 1, p. 289 (1837).

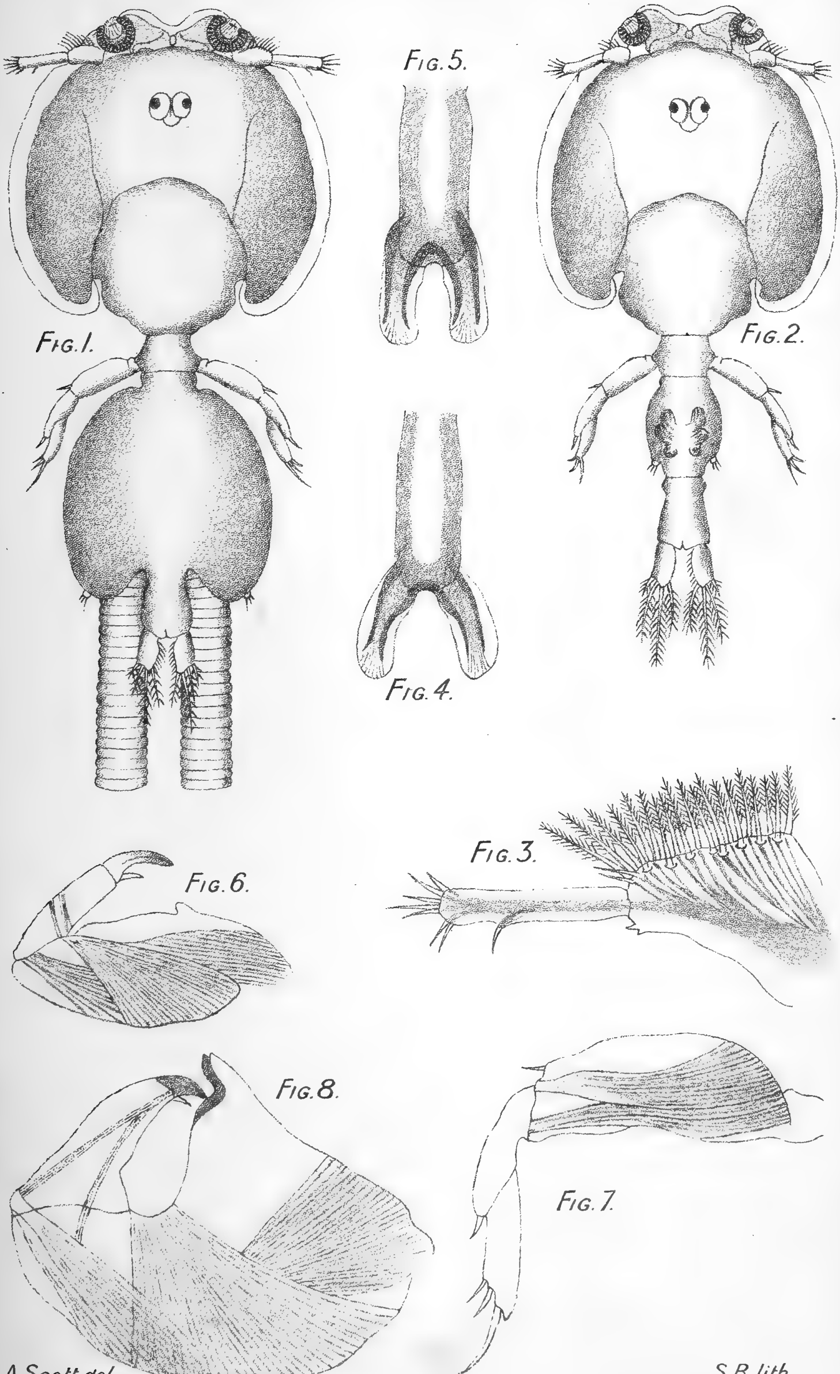
Attached to the gill-rakers of the Common Gurnard (*Trigla gurnardus*) from the offshore stations, April, 1901. Also from the gill-rakers of the Yellow Gurnard, caught off Conway.

NOTE.—The species recorded as *Chondracanthus radiatus*, Kr., in the paper by Mr. Thompson and myself, published in the Transactions last year, turns out to be *Chondracanthus merluccii*, Holten.

The species marked with an asterisk are described and figured by my father, Mr. T. Scott, in the XIX. Ann. Rept. Fishery Board for Scotland, part iii. For other fish parasites see XVIII. Ann. Rept. F.B.S.

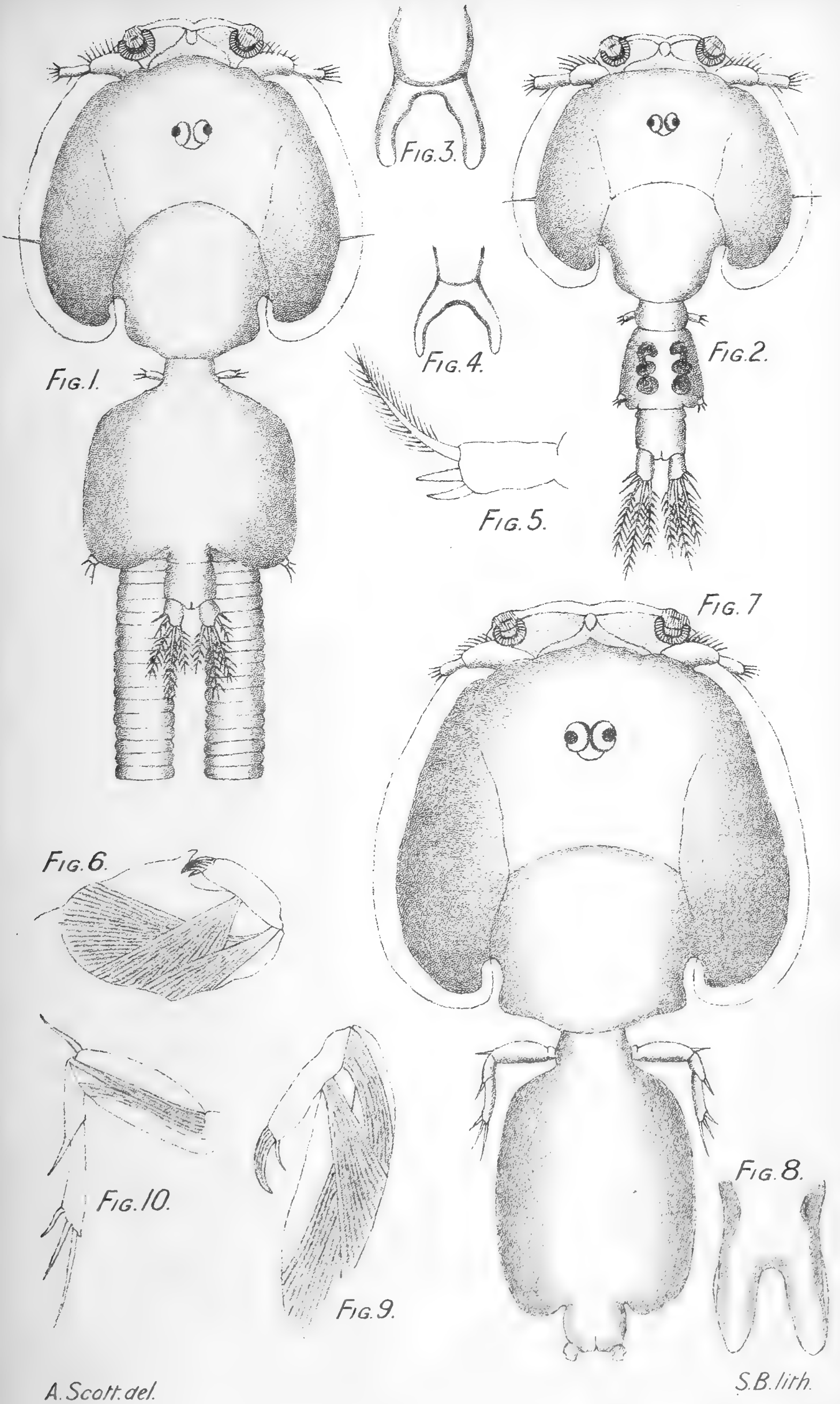
PIEL LABORATORY,

May 1, 1901.



A. Scott. del. S.B. lith.

CALIGUS MINIMUS, OTTO.



FIGS. 1-6. PSEUDOCALIGUS BREVIPEDES (B. SMITH).

,, 7-10. CALIGUS BREVICAUDATUS, n. sp.

Explanation of Plates.

Plate I.

Caligus minimus, Otto.

Fig. 1.	Mature female, dorsal view	× 19·25
Fig. 2.	Mature male, dorsal view	× 12·8
Fig. 3.	Antennule	× 100
Fig. 4.	Sternal fork, female	× 100
Fig. 5.	Sternal fork, male	× 100
Fig. 6.	Second maxilliped, female	× 77
Fig. 7.	Fourth foot	× 71
Fig. 8.	Second maxilliped, male	× 51

Plate II.

Pseudocaligus brevipedes (Basset Smith).

Fig. 1.	Mature female, dorsal view	× 22
Fig. 2.	Mature male, dorsal view	× 22
Fig. 3.	Sternal fork, female	× 77
Fig. 4.	Sternal fork, male	× 77
Fig. 5.	Fourth foot	× 145
Fig. 6.	Second maxilliped, male	× 77

Caligus brevicaudatus, n.sp.

Fig. 7.	Mature female, dorsal view	× 19·25
Fig. 8.	Sternal fork, female	× 77
Fig. 9.	Second maxilliped, female	× 75
Fig. 10.	Fourth foot	× 51

THE NECK GLANDS OF THE MARSUPIALIA.

By James Johnstone, B.Sc.

[Read May 10th, 1901.]

The following notes are a description of the relationships of the glands of the neck—the thymus organs, the thyroid, the submaxillary and parotid glands, in two marsupials, *Dendrolagus* and *Acrobates.* They are of interest in view of the discovery by Symington,* in 1898, of a superficial cervical thymus gland in many of these animals, an organ which so far as is known is not found in any other group of mammalia. It would appear from the forms already studied that this superficial thymus organ is characteristic of Diprotodont Marsupials, and indeed affords an additional distinction between these and the Polyprotodont families, and it seems very desirable, both on this account, and in view of the remarkable constancy in the relations of the thymus in other mammals, that as many genera as may be available should be described with this in mind. As a general rule little attention has been paid in most descriptions of the anatomy of Marsupials to the topography of the glands of the neck, and the presence of this remarkable thymus lobe has long been overlooked.

I am indebted to Mr. H. C. Robinson, Assistant in the Zoological Department, University College, Liverpool, for these two animals, which were collected for him. The *Dendrolagus* was a young male, measuring 31 cm. from the snout along the back to the root of the tail. It was either *D. lumholtzi* or *D. bennetti*, but I am unable to

* The Thymus Gland in the Marsupialia. Journ. Anat. and Physiology, vol. xii. (N.S.), 1898, pp. 278-291.

determine its species. *Dendrolagus*, the tree-kangaroo, is an arboreal macropid, which feeds on bark, leaves and fruit; *Acrobates*—the pigmy flying-phalanger—is a very small animal, smaller than a mouse, which is found in Queensland, N.S. Wales and Victoria. It too is arboreal, living

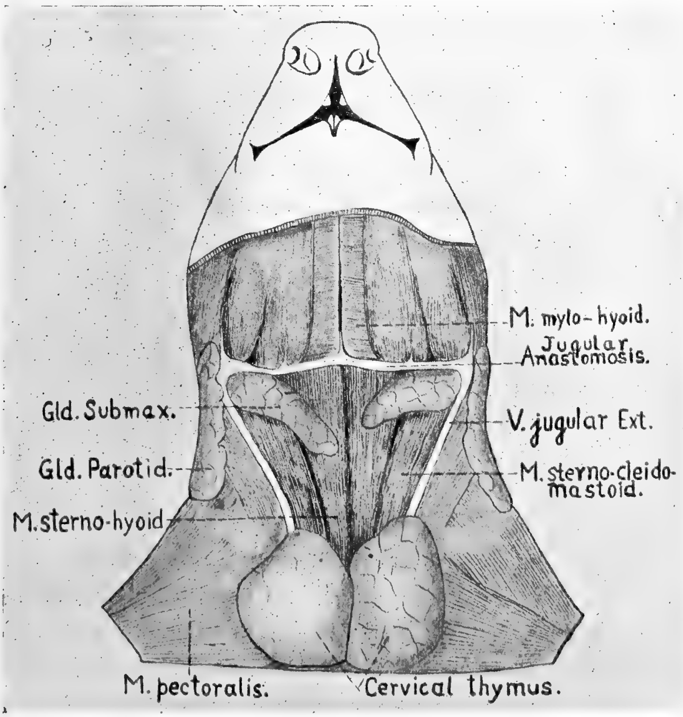


FIG. 1. *Dendrolagus;* superficial dissection of the neck—only the integument removed. Natural size.

on the honey, which it abstracts from flowers, and on fruit. Only one species, *pygmæus*, is known. The specimen described here was a male, measuring $13\frac{1}{2}$ cm. from the snout to the tip of the tail.

DENDROLAGUS (Figs. 1 and 2).

So far as I can find, only two descriptions of the visceral anatomy of this genus are in existence. Beddard* has described the abdominal viscera, certain of the great bloodvessels and the brain; Owen† gave some notes on the anatomy of a different species, and refers to the unusual size of the parotid glands. In the specimen I dissected, the superficial thymus was found with no other dissection than dividing the skin and platysma along the middle ventral line of the neck, and reflecting back the folds. The organ had two lobes of nearly equal size, the largest of which had a longitudinal diameter of about 20 mm., and a transverse diameter of 13 mm. It was situated on the upper part of the thoracic wall, covered only by skin and platysma, and lay mostly posterior to the anterior extremity of the sternum. The external jugular veins were connected by a wide anastomosing vessel at the transverse level of the angles of the lower jaw. The submaxillary glands were situated in the angles of the three vessels so formed. External to the jugulars, and only separated by these from the submaxillary glands, were the parotids, large thin sheets of glandular tissue, about 23 mm. in length, extending backwards to the ears on the lateral surfaces of the neck. All these glands were hardened, imbedded in paraffin, and sectioned. The preservation of the tissues was very bad, and no more of the minute structure of these organs could be ascertained than sufficed for their identification. In the thymus no obvious distinction into cortical and medullary portions could be made out. Hassall's corpuscles were however present.

* On the visceral anatomy and brain of *Dendrolagus bennetti*. Proc. Zool. Soc., 1895, pp. 131-137.

† Notes on the Anatomy of the Tree-Kangaroo (*Dendrolagus inustus*). Proc. Zool. Soc., 1852, pp. 103-107.

Fig. 2 is a representation of the anatomy of the deeper ventral part of the neck and thorax of the same animal. The thoracic thymus is seen occupying its typical mam-

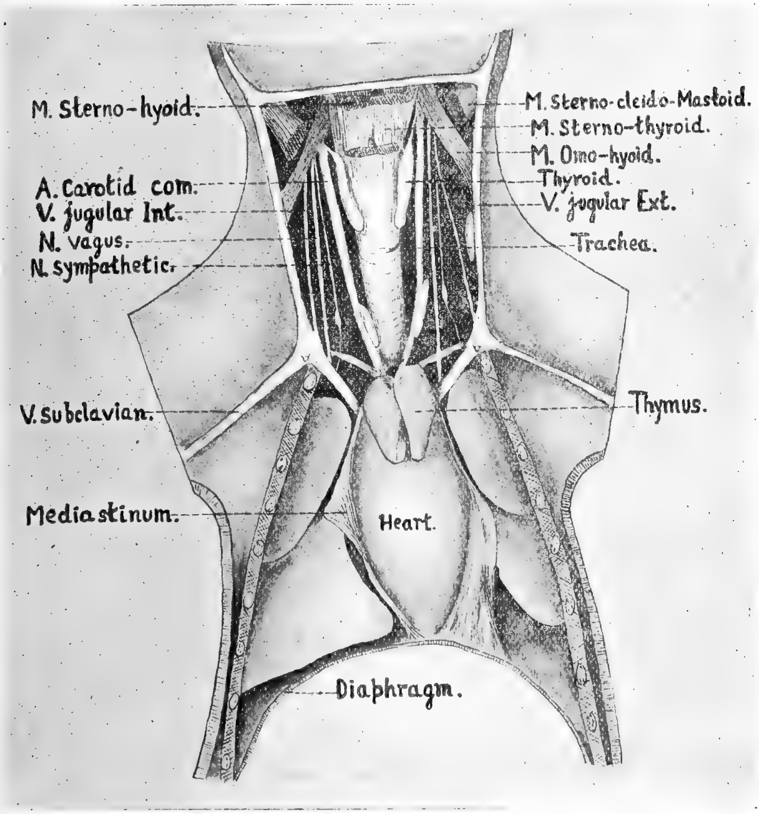


FIG. 2. *Dendrolagus*; dissection of the deeper parts of the neck and thorax. Natural size.

malian position in the anterior mediastinal cavity over the base of the heart. It consisted of two lobes, and was much smaller than the superficial organ. No extensive fatty degeneration had taken place. Smaller detached nodules of thymic tissue lay along the roots of the carotid arteries, and some larger masses are represented on the course of those vessels and on the internal surface of the left external jugular. Such portions of thymus tissue detached from the main gland, and lying in various positions in the neck or in close association with the thyroid, are of frequent occurrence in many mammals, and probably have no special morphological significance.

ACROBATES.

From a first examination it appeared that, contrary to expectation, the cervical thymus was absent in this animal. When the skin was divided in the middle line of the neck and reflected outwards, two large, paired, glandular masses were seen lying in the angle formed by the flexure of the head, in contact with each other by their internal surfaces, one slightly overlapping the other. Each of these was oval in shape, the transverse diameter was the longer, and measured about 8 mm. They were separated from the parotid glands, which occupied their usual positions, by the external jugular veins. On dissecting away these structures two other paired glandular masses were seen lying underneath, each about half the size of the more superficial mass and darker in appearance.

Closer examination showed that each of the two superficial glands was compound in nature; a very slight groove separated it into inner and outer portions. The inner portion was about one-third the size of the outer, and was paler in colour. The compound gland was hardened and sections were made. Sections were also made of the underlying lobes and of the parotid glands.

A section parallel to the transverse axis of the outer lobe showed two distinct organs. The inner smaller portion had all the characters of a thymus gland, except that cortical and medullary portions were not distinct. A few Hassall's corpuscles could be seen. This portion of the gland, which is evidently the cervical thymus lobe, was enclosed in the same sheath as the outer portion. The latter was a salivary gland. A few alveoli are represented in fig. 3 (3). It is evidently a mixed gland, contain-

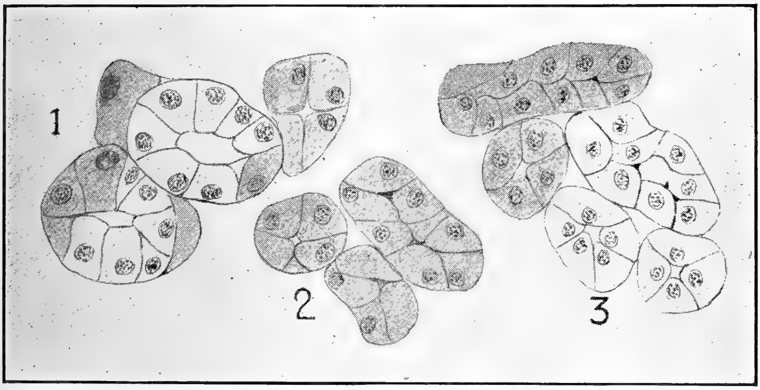


FIG. 3. *Acrobates*, portions of the salivary glands—1, lower lobe of submaxillary; 2, parotid; 3, upper lobe of submaxillary.

ing serous and mucous alveoli. The former are composed of cells, staining deeply, and with the nuclei about the centre of the cell. The latter are made up of cells staining lightly, and with the nuclei crowded round the lumen. The characters of the underlying lobes are represented in (1). The alveoli are larger, and as a rule their lumina were wider. The nuclei were near the external surfaces. Marginal or "crescent" cells were present, and some of the alveoli had the character of the darkly staining alveoli of (3). The parotid gland was of still another type; three alveoli are represented in (2). All are made up of darkly staining cells, as in the serous alveoli of fig. 3. The nuclei are, however, nearer the external surfaces of the cells.

The submaxillary gland, therefore, consists of two portions. One of these, a mixed gland, is bound up with the cervical thymus, to form one structure. The other lies underneath, and is a mucous gland. The parotid is a serous gland.

It may be useful to summarise here what has been made out regarding the presence of this cervical thymus organ in the families of the Marsupialia. Representative genera from all the six families have now been examined by Professor Symington,* and by myself,† and the relationships of thoracic and cervical thymus organs have been ascertained in these forms. The facts may be expressed in the form of a table.

Diprotodontia.	Polyprotodontia.
Superficial cervical thymus always present. Thoracic thymus usually present, but may be absent.	Superficial cervical thymus always absent. Thoracic thymus usually present, but varies as in other mammalia.
Macropodidæ:—	*Didelphyidæ*:—
Macropus bennetti.	Didelphys virginiana.
,, rufus.	,, pusilla.
,, wilcoxii.	,, murina.
,, eugenii.	*Dasyuridæ*:—
,, giganteus.	Dasyurus viverrinus.
,, rufus.	,, cancrivora.
Dendrolagus sp.	Thylacinus.
Phalangeridæ:—	Antechinomys lanigera.
Trichosurus vulpecula.	*Peramelidæ*:—
Phascolarctus cinereus.	Perameles gunni.
Acrobates pygmæus.	
Phascolomyidæ:—	
Phascolomys wombat.	

* Symington, Jour. Anat. Phys. loc. cit.

† Johnstone, Journ. Linnean Soc. London, vol. 26, pp. 537-557. 1898.

These are nearly all the forms examined. The results obtained from several others (not included) are rather doubtful, and renewed investigation is desirable. So far as the facts go, they support the view suggested by Symington, that the superficial cervical thymus is absent in polyprotodont marsupials, as in all other mammalia in which the anatomy of the neck has been investigated in sufficient detail, and is characteristic of Diprotodontia. The number of forms examined is still somewhat small, and it is desirable that the possible presence of a cervical thymic organ should be kept in mind in dissections of marsupials. It has been seen that this structure may enter into intimate association with the submaxillary gland, and its presence may be overlooked where such relations exist if the organs are not identified microscopically.

The morphology of the cervical thymus is obscure, and until its development has been worked out in sufficient detail little can be said as to its relation to the other organs arising from the embryonic branchial pouches. It appears probable that, like thymus and thyroid, it arises from one or other of the posterior pouches. It is now known that various other organs arise in connection with the thyroid and thymus glands, and may enter into variable relations with those structures. In connection with the thyroid (itself a compound structure), there are always two much smaller glandular bodies in association with each lateral thyroid lobe. These are the "glandulæ parathyroidæ" of Sandström (epithelial corpuscles of Kohn), and their development is now fairly well known.* One of these bodies, the internal epithelial corpuscle ("Glandule thyrodienne" of Simon) is always sunk in

* See C. Simon, Thyroide laterale et glandule thyroidienne chez les mammiferes. Nancy, 1896.

the tissue of the thyroid lobe, with which it is associated. It is derived from the lateral thyroid anlage, and so from the fourth branchial pouch. The other, the external epithelial corpuscle ("Glandule thymique" of Simon) always lies outside the thyroid lobe at a variable distance. It arises in association with the thymus from the third branchial pouch.

I have described elsewhere† a connection between the cervical thymus and the thyroid lobe of the same side in a foetal *Macropus*, in the form of a cord of cells uniting the two organs. This suggests a relation of the former organ to the thyroid rather than to the thymus organ in the mediastinal space. It is possibly the case that the cervical thymus may correspond to one of the epithelial corpuscles, though its minute structure does not resemble that of the latter (which, however, may be very variable), and its superficial position is against this view. The nature of the structure can be only a matter of conjecture, however, until its development is made known.

† Journ. Linnean Soc., London, vol. xxvi., p. 546.

A LIST OF THE HYMENOPTERA-ACULEATA SO FAR OBSERVED IN THE COUNTIES OF LANCASHIRE AND CHESHIRE, WITH NOTES ON THE HABITS OF THE GENERA.

By WILLOUGHBY GARDNER, F.L.S., F.R.G.S.

[Read May 10th, 1901.]

COMPARED with the generally favoured and now well-exploited Lepidoptera and Coleoptera, but little work has been done in the counties of Lancashire and Cheshire up to the present time in the order Hymenoptera. We have, however, had several observers here and there, who, during a series of years, have paid some attention to the Aculeata.

The first of these who has left us any records is that excellent entomologist the late Mr. Benjamin Cooke, who resided at Hazlegrove and afterwards at Southport, and whose observations extended not only around these places, but also especially over Delamere Forest and the Wirral. The result of his work is fortunately preserved to us in the "Naturalist" for December, 1879, and January, 1880. His records are marked B.C. in the following pages.

The next observer in our district was that well-known local naturalist the late Rev. H. H. Higgins, M.A., of Rainhill. He collected the Aculeata during a number of years in his own neighbourhood, and also at many other places in the two counties. He kindly handed over his notes to the writer, and they appear here under the initials H.H.H.

Other collectors who have at various times worked in the district are—Miss E. C. Tomlin, Chester—E.C.T. Mr. R. Newstead, F.E.S., Chester—R.N. Mr. J. Ray Hardy, Manchester—J.R.H. Mr. J. T. Green, Birkenhead—J.T.G. Their notes, and the full use of their collections, most generously given, have very largely contributed to the present list. The initials, as above, distinguish their several records in the text. Where no initials occur, the writer is himself responsible for the statement.

In the year 1892 a "Preliminary List of the Hymenoptera Aculeata of Lancashire and Cheshire" was published in the "British Naturalist," Vol. II., by the present writer, and included all observations made to that date. Since that time much less work has been done locally among the Aculeata than could have been wished, owing to our surviving observers being engaged in other researches, or else living outside the limits of our two counties. But some additions to our local Fauna have nevertheless been made, and our knowledge of the range of many species has been considerably extended, while one or two former records have been proved to require correction. Also, by the publication in 1896 of Mr. Edward Saunders' "Hymenoptera-Aculeata of the British Islands," changes have been made in nomenclature, &c., so that a new list has become still further necessary for our local faunistic literature.

It will be seen from the above list of our local workers that observations hitherto made have extended over but a portion of our two counties, and that therefore we are at present far short of sufficient data for a complete Aculeate-Hymenopterous Fauna of the district. Still, even as a basis for future work, it would appear to be desirable to bring together the information obtained up to date, and to this end the following paper is contributed to the Transactions of the Liverpool Biological Society.

The difficulty of naming obscure species correctly is often great. The writer and our local collectors, however, have had the kind and generous assistance of Mr. Edward Saunders, F.L.S., in this matter, which is hereby gratefully acknowledged.

In order to make a mere list of more interest to local entomologists who have as yet had no experience of the Aculeata, and who it is hoped may be induced to pay some attention to them in the future, a brief resumé of the interesting habits of the British genera is, by suggestion, included with the following records of our local species. For this the writer acknowledges much indebtedness to the works of Mr. Edward Saunders, Professor Pérez, Schuckard, F. Smith, and others, and also to various contributors to the "Ent. Mon. Magazine."

PHYSICAL GEOGRAPHY AND CLIMATOLOGY.

Physically our two counties of Lancashire and Cheshire consist chiefly of that extension of the great midland plain of England called the Western Plain, a long tract of level country lying between the high watershed of the Pennine Chain in the east and the Irish Sea and the mountains of Wales on the west. The limits of our faunistic district are thus roughly speaking natural ones. This broad plain is only broken by a few rocky ridges and hills cropping up here and there in heights varying from 300 to 600 feet; but along its eastern borders and in the north the continuous highlands become mountainous, and occasionally attain an altitude of as much as 1,900 feet.

I.—As regards its solid geology, the district mainly consists of sandstones of the Triassic age, varied in places by both newer and older formations. Along the eastern borders of Cheshire and projecting into the centre of South Lancashire, the older coal measures occupy the ground. From beneath these, again, the millstone grit crops up among the hills along the extreme eastern edge of the two counties, and also in parts of northern Lancashire. In the latter district other carboniferous rocks, including the mountain limestone, appear, while in the extreme north there is a mass of Silurian slate rocks. The Triassic formations are in great part covered by recent boulder clays and sands, which have filled the valleys and overspread the lower plains; large peat mosses, now much reduced by drainage and cultivation, also occur here and there; while along the western side are extensive tracts of post tertiary silts, &c., covered again near the sea coast by hillocks of blown sand.

II.—Such geological features naturally produce much local variety in the flora within the limits of our district. The central plain is for the most part cultivated, and therefore without marked feature; the low hills and ridges cropping up out of it are generally heath-covered or pine-clad sandy tracts, with the plants peculiar to such country; and the same may be said of our peat mosses. The limestone district of North Lancashire and the sandhill zone of our coasts each produce highly specialised floras; and the last-named, owing to lime from innumerable snail shells, also affords a home for many plants found in the former. Further, the absence of rocks along our shores ensures freedom from the salt spray so often destructive of vegetation along a coast line; so that for several reasons our sandhill flora is particularly rich.

III.—The mean annual temperature of the greater part of our district ranges between 40° and 50° Fahr., or about 5° lower than Central and Southern England; the mean summer readings average 60° to 61° Fahr., or three to four degrees less than the Thames Valley.

IV.—The annual rainfall over the greater part of Cheshire is 25 to 30 inches, about 5 inches more than the eastern half of England, including the lower Thames

Valley; but to the N.E. of the county it rises to 30 to 40 inches. The latter figures also represent the fall over the S. and S.W. of Lancashire, while in the high ground along the N.E. and the extreme N. the amount increases to as much as 40 to 50 inches.

V.—The sunshine of our district has been averaged approximately at about 1,400 hours per annum; there is rather more along our dry, sandy coasts, and, owing to the smoke of large manufacturing towns, much less in many inland parts of Lancashire. The average is about equal to that of the Midlands and the Thames Valley, but about 100 hours less than the lower Severn Valley and the more southern and eastern parts of England, and 200 to 250 hours less than the extreme South and South-eastern coasts.

VI.—The winds of our district are largely westerly, with a mean annual velocity of 15 miles an hour—excessive, compared with the Midlands and South and East of England.

VII.—Another feature which has much effect in several ways upon the fauna of a district is its population. Cheshire is still mainly rural, having, even reckoning for its towns, about an acre of ground to each person. In Lancashire, the proportion is only about a quarter of an acre per person, making it the most thickly populated county in England next to Middlesex: and this notwithstanding large tracts of waste or sparsely-inhabited country in the North and West, so that the South and South-east is very densely peopled indeed, town succeeding town, with all their attendant destructive effects upon flora and fauna.

From the above it will be seen that the counties of Lancashire and Cheshire afford the Hymenoptera-Aculeata—

I.—Excellent localities for nidification, both in the frequent escarpments of crumbling Triassic sandstone inland, and in the sandhills of the coast—both places where many species delight to burrow; also considerable variety of soil, including plenty of clay, for other specialised species. The mountainous and limestone country in the North, as yet unworked by local Hymenopterists, should produce additions to our fauna, as well as the high hills extending along the East.

II.—A varied flora, rich in flowers frequented by Aculeates, especially in the sandhills districts, which are already attractive to them as good places for their burrows. The uncultivated pine and heather-clad regions also favour many species.

III., IV., V. and VI.—The Aculeate Hymenoptera delight above all things in warmth, dryness, sunshine and absence of wind; cold and wet in their breeding seasons are very destructive to them. From this it will be seen that our sandy coasts are again more suited to the Aculeates than our inland localities, but that our district as a whole compares very unfavourably with others in the Midlands and in the east and south of England in respect of climate. This probably explains the undoubted scarcity of these insects in Lancashire and Cheshire, compared with their great abundance in many districts more favoured meteorologically. Very many common species which are seen in profusion further south, require to be searched for in order to discover them here in ordinary seasons, though nearly all have occasional years when they appear more numerously.

VII.—The growth of our population, with resultant building operations, smoke, fog and reduced sunshine, as well as golf clubs and "summer camps," have caused many species of the gregarious burrowing Aculeates to disappear entirely from former favourite breeding places; this will be noticed more particularly later.

On the whole, however, the Aculeate Hymenoptera possess greater power of adaptability to circumstances than insects of other orders. The Lepidoptera, for instance, with their many special-plant-fed larvæ, certainly depend more upon the flora, and consequently upon the geology of a district, for their distribution than the Aculeata. The connection between the fertilising bees and the honey and pollen yielding flowers is of course great; but the relationship is usually a broad one between families or genera respectively, and is only occasionally confined to the limits of species. Many bees undoubtedly show a marked preference for certain flowers, but, in their absence, they usually find other nearly-related species to suit their tastes. Hence the Aculeate-Hymenopterous fauna of our district seems to be more ubiquitous in its distribution than our flora, or than several of the other sections of our insect fauna.

HYMENOPTERA-ACULEATA.

PRÆDONES.

Insects both solitary and social in their habits, comprising the Ants, and the various kinds of Wasps.

HETEROGYNA.

Social Ants, consisting of males and females, both usually winged, and also workers, or imperfect females, which are apterous. They dwell, with few exceptions, in large communities, constructing for themselves very elaborate nests; in these they rear their larvæ, which are fed upon honey by the worker ants. The economy and instinct of these insects is very remarkable and wonderful, and places them high in the scale of invertebrate life. Some ants have apparently no homes of their own, but live in the nests of others, as *Formicoxenus* with *Formica rufa*; while one British species, *Formica sanguinea*, actually steals the pupæ of another, *F. fusca*, from their dwellings, and rears them up as workers or "slaves" in its own nest. Many species introduce and keep various Aphides within their nests, for the sake of the "honey" which they emit. Others harbour certain Coleoptera in their dwellings, some of which, as the curious blind *Claviger*, which they feed and tend with care, would appear to be of some unknown value or interest to the ants. Very many beetles, chiefly belonging to the *Staphylinidæ*, are more or less peculiar to ants' nests, where they dwell, and sometimes even pass their metamorphoses; others again occur there probably as plunderers, or even casual visitors in search of warmth and shelter; altogether about seventy species of Coleoptera have been found associated with ants in Britain. Of other insects, certain *Coccidæ* are regularly found in ants' nests, where they seem to be carefully cared for by their hosts; also a species of wood-louse.

Formicidæ.

Most of our English species come under the head of Mining Ants, forming extensive burrows and excavations for their nests in various situations; some in the earth, either in banks (*F. fusca, L. niger, L. umbratus* and *T. erratica*) or in raised "ant-hills" or under stones (*L. flavus*), and some in decayed wood (*L. fuliginosus* and occasionally *F. fusca, L. niger, L. umbratus*). The three non-mining species (*F. rufa, F. sanguinea* and *F. exsecta*) construct pyramidal nests of twigs, leaves, &c., above ground. The pupæ of the *Formicidæ* are generally enclosed in silken cocoons. The nests of this family usually contain more myrmecophilous Coleoptera than those of other ants, the most frequented being those of *F. rufa*, *L. fuliginosus* and *L. flavus*. The *Formicidæ* so far observed in our district are:—

Formica, Linn.

F. rufa, Linn.—Only noted so far in Delamere Forest, E.C.T., and Dunham Park, J.R.H.

F. fusca, Latr.—Common in the district.

race *cunicularia*, Latr.—Taken at Greenfield, B.C.

Lasius, Fab. = *Formica*, pars., Smith.

L. fuliginosus, Latr.—Hoylake and West Kirby; Delamere and Bowden, B.C., Bolton district, C. E. Stott.

L. niger, Linn.—Our common garden ant.

L. umbratus, Nyl., *brunneus*, Sm.—Bowden, B.C.

L. flavus, De Geer.—Abundant everywhere. The large Aphis *Paracletus cimiciformis* in its nests at Delamere, R.N.

Poneridæ.

Another family of Mining Ants, forming nests in the earth (*P. contracta*) and in houses (*P. punctatissima*).

Ponera, Latr.

P. contracta, Latr.—Once near Manchester, B.C.

Myrmicidæ.

Very similar in habits to the *Formicidæ*, generally excavating nests either in the ground (*M. rubra*, *T. cæspitum*, and sometimes *L. acervorum* and *L. tuberum*), or in wood (*L. acervorum*, *L. tuberum* and sometimes *M. rubra*). One species, however, *Formicoxenus nitidulus*, lives in the nests of *F. rufa*, and another, *Solenopsis fugax*, burrows in the walls of the dwellings of various ants. The pupæ of the *Myrmicidæ* are naked, unlike those of most of the *Formicidæ*, which are in cocoons. The nests of the genus *Myrmica* harbour one or two myrmecophilous Coleoptera, and those of *Tapinoma* a single rare species.

Leptothorax, Mayr.

L. acervorum, Fab.—Delamere Forest, E.C.T. Found in nest of *F. fusca* on Bidston Hill by Mr. Henry Burns. This is an unusual habitat, as it generally forms colonies in the ground, under bark of trees, in dead wood or bramble stems.

Myrmica, Latr.

M. rubra, Linn.

race *ruginodis*, Nyl. — Abundant near Manchester, B.C.

race *lævinodis*, Nyl.—Hoylake and West Kirby; Bowden, B.C.; Chester and Delamere, E.C.T.

race *scabrinodis*, Nyl.—Common everywhere.

race *lobicornis*, Nyl.—This rare variety has been taken near Bowden, B.C.

Monomorium Pharaonis, Linn.—*Diplorhoptrum domesticum*, Sm.—This introduced species is now often a pest in houses in our towns.

FOSSORES.

Solitary insects, consisting of male and female only, and without workers, as found in the previous social division. They comprise certain Ants and the majority of our species of Wasps. They feed on honey gathered from flowers in the imago state, but the larvæ are carnivorous. Though solitary in habit (*i.e.*, the female constructs a single nest for herself, instead of the common one, containing several hundred individuals, of the social ants and wasps), the Fossores often form large colonies of many separate burrows in close proximity. According to her species, the female wasp excavates a little tunnel either in sand, mud, dead wood or other suitable material; there she deposits her egg, and then stores up as sustenance for the future grub, which she herself will never live to see, such animal food as Lepidopterous larvæ, Diptera, Coleoptera, other Hymenoptera, Hemiptera and Arachnidæ. These products of the chase are placed in the burrows alive, but reduced to a state of paralyzis by the poison of the captor's sting; they apparently die about the time the egg hatches and the young larva requires food. It is probable that some few species, such as those belonging to the *Mutillidæ*, are inquiline upon other insects, and thus form exceptions to the above general rule of life among the *Fossores*.

The Hymenopterous *Chrysididæ* are parasitic upon the larvæ of some of the *Fossores*, *e.g.*, *Hedychrum* upon *Mimesa*, *Hedychrum* and *Chrysis* upon *Astata*, and the ubiquitous *C. ignita* upon other genera. Certain *Diptera* are also said to have been bred from their nest cells.

MUTILLIDÆ.

Solitary Ants, with winged males and apterous females. Their habits are but little known; they are very probably inquiline upon the insects whose nests they have been observed to frequent.

Mutilla europæa has been found in the nests of the genus *Bombus*, and *Myrmosa melanocephala* with *Halictus*, *Megachile* and *Vespa*.

Myrmosa, Latr.

M. melanocephala, Fab.—Only recorded so far from Delamere, B.C., though it is not infrequent in North Wales about burrows of *Halictus rubicundus* and other Aculeates.

Tiphiidæ.

The first family of the Solitary Wasps, with both males and females winged. The life histories of our two British species of *Tiphia* do not appear to be worked out. The females of *T. minuta* have been found under cow-dung, and possibly prey upon *Aphodii.* Neither of the species have yet been recorded from our district.

Sapygidæ.

Another family of Solitary Wasps. The female usually forms cells for her eggs in a burrow previously excavated by some other insect (*e.g.*, a *Colletes, Chelostoma,* or *Osmia*), in the ground or in wood; she sometimes makes use of a deserted snail shell. As food for her offspring she stores up the larvæ of Lepidoptera.

Sapyga, Latr.

S. 5-*punctata,* Fab.—Rainhill, H.H.H.; Upton, near Chester, at burrows in old barn wall, E.C.T.

Pompilidæ.

The agile members of this large family of Sandwasps often burrow in sandhills by the seaside (*Pompilus rufipes, plumbeus, niger,* and *gibbus*), in rubble walls (*A. variegata*) or in wood. Nearly all the species prey exclusively upon spiders. *P. niger,* however, is said to sometimes store up the larvæ of Lepidoptera.

Pompilus, Fab.

P. rufipes, Linn.—Southport sandhills, B.C.

P. plumbeus, Fab.—*pulcher,* Shuck.—Wallasey sandhills, exceedingly abundant some years; Southport sandhills, B.C.

P. niger, Fab.—*approximatus*, Sm., *melanarius*, Bond.—On the coast at Southport, B.C., and inland at Hazlegrove, B.C.

P. gibbus, Fab.—*trivialis*, Dhlb., Thoms., &c.—Common in district.

P. pectinipes, V. d. Lind.—*crassicornis*, Shuck, Sm., ♀ Southport, B.C.

Salius, Fab. (*Priocnemis*, Schiödte).

S. exaltatus, Fab.—Only recorded so far from Bowden, B.C., and Delamere, E.C.T. and B.C.

Ceropales, Latr.

C. maculata, Fab.—Only noted at Southport, B.C., though probably occurs elsewhere on our sandhills, as it is common on North Wales coast.

SPHEGIDÆ.

A large and comprehensive family of Wasps, of which the genera vary greatly in form and also in habits, as noted below.

Astata, Latr.—The females burrow in hard sand. They prey upon various larvæ.

A. stigma, Panz.—*jaculator*, Sm. (Zool).—This, till recently, rare species has been twice recorded from our district, one specimen having been taken at Southport by Mr. B. Cooke, on 25th June, 1879, and another on Wallasey sandhills by myself, on the 5th July, 1891, (*v.* Ent. Mon. Mag., Jan., 1892). It should be searched for, as it has also occurred upon the North Wales coast. It loves the hottest sunshine, and has an excellent habit of returning to the spot again after being disturbed. The male is easily detected, when running among other similarly coloured sand-wasps, by a brilliant white spot on its face.

Tachytes, Panz.—The females excavate tunnels in sand, and are stated to store up for their offspring larvæ of both Lepidoptera and Orthoptera.

T. pectinipes, Linn.—*pompiliformis*, Sm.—Wallasey sandhills; Oakmere, Delamere, E.C.T.

Dinetus, Jur.—Allied to last-named genus; only taken very rarely in South of England.

Miscophus, Jur.—Our two British species burrow in sandy places like *Tachytes*, but provision their cells with spiders. They have not been observed in our district.

Trypoxylon, Latr.—The several species excavate their little tunnels in various different situations, *T. figulus* either in banks of light earth or in wooden posts, often in colonies, *T. clavicerum* in old timber, and *T. attenuatum* in briar stems. Spiders are stored up as food.

T. figulus, Linn.—Only reported so far from Bowden, B.C., but probably overlooked, as common in North Wales.

Ammophila, Kirb.—The nest cells of these formidable looking sand-wasps are at the end of a burrow excavated in a bank of earth or sand. The prey of the various species consists of Lepidopterous larvæ, with the exception of *A. hirsuta*, which apparently confines its attention to spiders.

A. sabulosa, Linn.—Our most abundant species of this genus, extending along the coast from Hoylake to Southport. Inland also at Delamere, E.C.T.

A. hirsuta, Scop.—*viatica*, Sm.—Taken on sandhills at Southport, B.C. and J.R.H., and at Formby, H.H.H. and F. Birch. Observed once carrying *Pyralidæ*, J.R.H., though on North Wales coast, where abundant, it stores spiders.

A. lutaria, Fab.—Brought to me from sandhills at Blackpool, by Mr. C. E. Stott.

Spilomena, Schuk.—Our one very small British species burrows in sand, or sometimes in dead wood or bramble stems. It is said to store up a Coccid for its young. It has not yet been observed in our district.

Stigmus, Jur.—Nearly related to the last genus. Our one British species is said to make its nest in holes in dead wood, &c., and to provision its cells with *Aphides*; another account says it is parasitical. Not recorded, so far, from Lancashire or Cheshire.

Pemphredon, Latr.—The females burrow in dead tree trunks, posts, &c., (*P. lugubris*), or in rose and bramble stems (*P. shuckardi* and *lethifer*). They prey upon *Aphides* collected from roses and other plants.

P. lugubris, Latr.—Well distributed in district. Storing the Aphis *Melanoxanthus salicis* in its cells at Ince, R.N.

P. shuckardi, Moraw.—*unicolor*, Thoms.—Also widespread.

P. lethifer, Schuck.—Similarly abundant.

Diodontus, Curt.—Excavates its nest in sandy banks (*D. minutus*), or in mortar of walls and in bramble stems (*D. tristis*).

D. minutus, Fab.—Only noted as yet from Bowden, B.C.

Passalœcus, Shuck.—The females make their cells in dead wood or in bramble stems. This genus has not yet been observed in our district, though the writer has taken *P. insignis* over the border in North Wales.

Mimesa, Shuck.—Females burrow in colonies in sandy places, and occasionally in holes in dead wood or in straws (*M. unicolor*). They store up *Aphides* and allied insects for their young. A Chrysid is said to be parasitical upon this genus.

M. bicolor, Fab.—Delamere, B.C.

Psen, Latr.—Breeds in holes in dead wood, in bramble stems, or in straws, and provisions its cells with *Aphides*.

P. pallipes, Panz.—*atratus*, Panz, Shuck, &c.—Only noted from Manchester and Bowden, B.C., and near Birkenhead, J.T.G. Probably overlooked elsewhere.

Gorytes, Latr.—But little seems to be known of the economy of this wasp-like genus. The females apparently deposit their eggs in ready-made holes in dead wood, &c.

G. mystaceus, Linn.—Halsnead, H.H.H.; Manchester, Bowden, Hazlegrove and Marple, B.C.; and Barleymore Wood, near Withington, J.R.H.

Nysson, Latr.—Probably nearly related in habits to *Gorytes*.

N. spinosus, Fab.—Common in the district, B.C.

Didineis, Wesm.—A genus with a single species in Britain, of which the life history does not appear to be known. It has not occurred in our district.

Mellinus, Fab.—The variable *M. arvensis* burrows gregariously in sandy banks. It preys upon various Dipterous insects—*Muscidæ*, *Syrphidæ*, &c.

M. arvensis, Linn.—Well distributed and often very abundant.

Philanthus, Fab.—The one British species of this genus provisions its nest with various wild bees (*Andrenidæ* and *Halicti*) and also with the honey bee (*Apis mellifica*). On the Continent it is sometimes very destructive in apiaries, stinging and carrying off the bees in great numbers. Fortunately it is very rare in Britain, and has not been seen so far north as our neighbourhood.

Cerceris, Fab.—The species comprising this genus are gregarious, and form tunnels in the ground; some, as *C. arenaria*, preferring loose sand, and others, as *C. interrupta*, choosing hard trodden pathways. The prey is various, according to species; wild bees, *Halicti* and occasionally *Andrenidæ*, are stored up by *C. ornata*, and different kinds of beetles by *C. arenaria* (*Curculionidæ*), *C. interrupta* (*Apionidæ*) and *C. labiata* (*Halticidæ*).

C. arenaria, Linn.—Formerly common on the Cheshire sandhills, B.C., but not observed there during recent years, though still abundant on the North Wales coast.

Oxybelus, Latr.—The females make their burrows in sandy places, and provision their cells with certain Diptera, some of which the various species mimic strongly both in form and in action.

O. uniglumis, Linn.—Abundant, burrowing in loose sand, on Cheshire coast. Extends northward to Southport, B.C. Inland also at Bowden, B.C., and at Rock Ferry, where a specimen nearly black once taken, J.T.G.

O. mucronatus, Fab.—*argentatus*, Curt.—*ferox*, Shuck.—This rare and beautiful species was taken on the Cheshire sandhills, opposite Liverpool, by Mr. Matthews prior to 1836 (*v.* Schuckard's "Fossorial Hymenoptera.") The locality has since been built over. It was also captured on Wallasey sandhills more recently, B.C., but does not appear to survive there now. It still occurs on the North Wales coast.

Crabro, Fab.—This large genus contains species with very various places of nidification. Some form burrows in sandy banks (*C. varius, westmæli,* *cribrarius, peltarius, scutellatus*), some in the mortar of old walls (*C. elongatulus*), some in decayed wood (*C. leucostoma, gonager, dimidiatus, signatus, cephalotes quadrimaculatus, vagus, interruptus, chrysostomus*), and some in bramble and rose sticks (*C. tibialis, clavipes, capitosus*). The food stored up for the future grub includes various kinds of Diptera (*C. leucostoma, podagricus, westmæli, dimidiatus, cephalotes, quadri maculatus, cribrarius, peltarius, vagus interruptus, chrysostoma*), and Aphides (*C. gonager* and *elongatulus*).

C. clavipes, Linn.—*rufiventris*, Panz.—Generally distributed, B.C.; specially noted Higher Bebington, J.T.G.

C. leucostomus, Linn.—Fairly distributed. Nests in rotten willow at Ince stored with *Syrphidæ*, R.N.

C. podagricus, V. d. Lind.—Only recorded from Hazlegrove, B.C.

C. palmipes, Linn.—*tarsatus*, Shuck.—Garden at Thorpe Villa, Chester, E.C.T.

C. elongatulus, V. d. Lind.—*luteipalpis*, Shuck.—*propinquus*, Schuck.—*obliquus*, Schuck.—*hyalinus*, Shuck.—Manchester, Hazlegrove, Delamere and Cheshire coast, B.C.

C. dimidiatus, Fab.—Chester and Delamere, E.C.T.; Cheshire coast, B.C.; and West Kirby, with a remarkable variety of male almost black, J.T.G.

C. vagabundus, Panz.—Higher Bebington, J.T.G.; Delamere, E.C.T., and "commonly distributed," B.C.

C. cephalotes, Panz.—*sexcinctus*, Sm.—*interstinctus*, Sm.? —Only reported as yet from Bowden, B.C., and

Bollin river valley, burrowing in willow stumps, J.R.H.

C. 4-maculatus, Fab.—*subpunctatus*, Shuck.—Not uncommon. Specially noted from Chester, E.C.T., Delamere, E.C.T. and B.C., and Bowden, B.C.

C. cribrarius, Linn.—Usually common in sandy places, where it burrows, *e.g.*, Wallasey, H.H.H., West Kirby, J.T.G., Cuddington, R.N., Delamere, E.C.T., and Bollin Valley, J.R.H.

C. peltarius, Schreb.—*patellatus*, Panz.—Well distributed; Hoylake; West Kirby, J.T.G., Cheshire coast and Southport, B.C., Oakmere, Delamere, J. Arkle, and Manchester, B.C.

C. interruptus, De Geer.—*Lindenius*, Shuck.—Taken on the Cheshire coast, B.C.

C. chrysostomus, Lep.—*xylurgus*, Shuck.—Equally well distributed, *e.g.*, Cheshire coast, B.C., Bebington, J.T.G., Ince, R.N., Eaton, near Chester, E.C.T.

Entomognathus, Dahlb.—The only British species of this genus is very similar in its habits to *Crabro*. It has not yet been noted in our district.

DIPLOPTERA.

Containing the true Wasps, with wings longitudinally folded, instead of flat and unfolded, as in the *Fossores*. There are two families in Britain, the one social and the other solitary in habit. These insects feed chiefly on vegetable diet, honey from flowers, fruit, &c., in the imago state, but the larvæ are carnivorous, like those of the *Fossores*.

VESPIDÆ.

Vespa, Linn.—A genus consisting of the well-known Social Wasps, which have not only perfect males and females, but also workers, or imperfect females. They dwell together in communities, sometimes containing over 2,000 individuals, in wonderfully constructed nests made of wood paper. These nests are placed in various situations by the different species. Some (*V. germanica, vulgaris* and *rufa*) usually select a ready-made hole in the ground, or other suitable cavity; others (*V. sylvestris* usually, and *norvegica* invariably) hang their nests exposed in bushes and trees. The "paper" material made by the latter is stout and tough to withstand the weather, while that of the ground builders is thin and fragile. Unlike the larvæ of the solitary *Fossores*, feeding upon insects paralyzed by the sting of the parent wasp, and stored up by her in the burrows for their use after her death, the young grubs of the genus *Vespa* are fed regularly by the workers living with them in the nests. Their diet consists mainly of insects or other animal food, which is semi-masticated by their devoted attendants before it is supplied to them.

Like those of the ants, the nests of our social wasps are regularly inhabited by certain other insects belonging to various orders. The list of inmates hitherto found in wasps' nests includes some seventy-five species of Coleoptera, about ten species of Diptera, a few Hemiptera, several Hymenoptera, and certain Acarida and Crustacea. Some are foes, others possibly friends, useful as scavengers, &c., but very many are merely casual pilferers or visitors. Certain Coleoptera pass their metamorphoses in the nests of various wasps. The curious *Metœcus paradoxus, L.*, feeds upon the grubs of its host, choosing *V. vulgaris* and *V. rufa.* *Velleius dilitatus, F*, breeds in the nests of *V. crabro* and *V. germanica*, and several *Quedii* and *Cryptophagi* in those of the three ground building species. Many Diptera are also found in wasps' nests in the larval state, although they have other habitats as well; such are species of the genera *Volucella, Acanthiptera* and *Homolomyia*, some of which mimic the wasps their hosts. Of Hymenoptera, the ichneumon *Sphegophaga vesparum*, Curt., lays its eggs on the grubs of several members of the genus *Vespa*, upon which its larvæ feed, and the parasitical *Chrysis ignita* also preys upon *V. rufa* and *vulgaris*. The inquiline and nearly allied wasp, *Pseudo-vespa austriaca* breeds in the nest cells of *V. rufa*, and *Myrmosa melancephalus* has been found dwelling with *V. sylvestris*.

V. crabro, Linn.—This species sometimes occurs in our towns, apparently imported with fruit and vegetables from the south. The only nest known to have been found in our district, viz., from Hawkshead, North Lancashire, is preserved in Owens Coll. Museum at Manchester.

V. vulgaris, Linn.—Abundant everywhere. A nest of this ground wasp was found built to a rafter in an outhouse at Malpas, R.N.

In years when wasps have been specially abundant in this district, as in 1889 and 1893, the writer has frequently seen this species preying upon both honey and humble bees. Its habit is to pounce down upon its quarry on flowers, and then, especially in the case of a female humble bee, the battle often waxes sore. The intrepid little worker wasp first bites off the great bee's antennæ, so making it more or less helpless; then it chops off the luckless creature's wings and legs; finally, with its powerful mandibles, it carves the body of its prey into two or more sections, and carries them off to its nest. Things do not always happen so, however, for on one occasion a bee was observed to curl its abdomen round and to sting its aggressor upon the tongue, a proceeding which caused the wasp to depart much disconcerted.

This and the following species have been noticed to swarm upon flower spikes of *Tritoma uvaria*, with the honey of which they seem to become quite intoxicated. Mr. Newstead has observed the same effect to be produced upon them by the honey of *Fuschia*.

The Coleopterous parasite *Metæcus paradoxus*, which is specially attached to this species and to *V. rufa*, has been taken in its nest at Manley, R.N., at Chat Moss, J.R.H., and on the southern borders of Cheshire by Mr. H. Locke.

V. germanica, Fab.—Very abundant. This ground wasp not infrequently constructs hanging embryo nests in wooden beehives in our district.

Mr. Newstead has devoted much time to specially investigating the insects found in nests of this and the preceding species. During one season he took about a hundred wasps' nests at Ince, near Chester, and in North Wales. His very interesting observations are recorded in detail in Ent. Mon. Mag., Vol. XXVII., pp. 39-41. In brief, the nests opened in Cheshire produced: — Coleoptera — *Quedius puncticollis* Thoms.—numerous larvæ and three imagos, Oct., in nests of *V. vulgaris*. *Cryptophagus pubescens*, Sturm.—abundant August to April in many nests of *V. germanica* and *vulgaris*. *C. setulosus*, Sturm.—sparingly in nests of *V. vulgaris*. *Metœcus paradoxus*, L.—several in August in single nest of *V. vulgaris*, at Manley. Also a few other casual visitors.. Diptera—*Cyrtoneura stabulans*, Fall.—abundant August to April (imagoes and pupæ) in nests of *V. vulgaris*. *Homolomyia canicularis*, L.—abundant, August to April, in nests of *V. germanica*, and sparingly in those of *V. vulgaris*. (larvæ, probably scavengers). *H. vesparea*, Meade.—two imagoes of this species, which was new to science (*v.* Ent. Mon. Mag., XXVII., p. 42), bred 26th July, from larvæ in the nest of *V. vulgaris*, at Ince. *Phora rufipes*, Meig.—occurred in every nest examined in August and September. *Acanthiptera inanis*, Fall.—larvæ of this rare species swarmed in October in a single nest of *V. germanica*, at Ince; imagoes bred following July. *Volucella bombylans*, L., var. *plumosa*.—larvæ abundant in nests of *V. germanica*, August to October. Acarida—*Uropada elongata*, Halliday.—seven nymphs attached to *H. canicularis*, bred from nest of *V. germanica*, in October. *Glyciphagus spinigus*.—swarmed in a nest of *V. germanica* on Chester Cop. *Tyroglyphus*, sp. ?—swarmed in some nests of *V. germanica*, August to October. Crustacea—*Porcellio scaber*, Latr.—in almost every nest. It is worthy of remark that none of the hundred or more nests examined apparently contained either the wasp-ichneumon, *Sphegophaga vesparum*, or *Chrysis ignita*.

V. rufa, Linn.—Well distributed both in Lancashire and Cheshire, though this timid and small colonied species is never common.

V. sylvestris, Scop.—*holsatica*, Fab.—Not infrequent all over the district. Specially noted at West Kirby and Eastham, where a variety without dot on clypeus; at Chester, R.N. and E.C.T.; at Rainhill, H.H.H., and around Bolton, C. E. Stott. Males once observed "assembling" in numbers to the female, after the habit of certain Lepidoptera.

V. norvegica, Fab.—*brittanica*, Leach.—Widely distributed in district, especially where fir trees occur, and perhaps, after *vulgaris* and *germanica*, our most abundant wasp in Cheshire. Particularly noted at Stourton, Oxton, Bidston, and near Wallasey and West Kirby; all round Chester, R.N. and E.C.T., and Delamere, B.C. and E.C.T. Although Mr. Newstead has examined many nests of this species, he has not found any insects frequenting them.

Pseudo-vespa, Schmeid.—A genus very nearly related to the last, but differing in life history. The one British species, *P. austriaca*, Panz., lives as an inquiline in the nests of *V. rufa*. It has no worker, like the social wasps, only male and female. The latter lays her eggs, after the manner of a cuckoo, in the nest of her host, and the grubs feed or are fed there at the expense of the rightful inmates of the colony. *P. austriaca* has not yet been recorded from our district, but Mr. Newstead and the writer have both taken it several times at different localities in North Wales, so it will probably turn up. It is easily distinguishable upon the wing by its slow and listless flight, in contradistinction to the busy activity displayed by the social wasps.

[*Pollistes binotatus*, Saus.—A specimen of an exotic wasp so labelled is in the Free Museum, Liverpool. It was taken in an undoubtedly wild state upon a flower at Ince Blundell, by Mr. W. H. Mountfield, in 1875. It was probably originally imported with goods from abroad, as another example apparently similar has since been captured in the Liverpool Docks.]

EUMENIDÆ.

"Solitary" wasps, with male and female only, and no worker, as in the genus *Vespa.* The species of the genus *Odynerus* are called "mason wasps," and construct their cells of sand and mud in various situations. Some burrow in sandy banks (*O. antilope* and *crassicornis*), some in dead wood (*O. trifasciatus*), some in bramble sticks (*O. lævipes* and *melanocephalus*), while others select such ready-made cavities as crevices in doors, keyholes, &c. (*O. parietum* and *antilope*). *O. spinipes* is noticeable for the remarkable nest which it makes in mud banks; this is furnished with a most beautiful projecting entrance tube, of an inch or more in length, curving downwards, constructed of small pellets of dried mud. *O. reniformis* also makes a somewhat similar nest. The *Odyneri* prey chiefly upon the larvæ of Lepidoptera, storing them up alive in their cells, after paralyzing with their stings, like the *Fossores.*

Our one British species of the genus *Eumenes* does not form several cells in a tunnel or cavity like the *Odyneri*, but constructs beautiful little mud cells, looking something like the nest of a tree-building *Vespa* in miniature, which it hangs among the stalks of heather and other plants. The female stores up small Lepidopterous larvæ for her future young.

The brilliant Hymenopterous *Chrysididæ* are specially parasitic upon the *Odyneri*, and sometimes prove very destructive to them. *Chrysis neglecta* devours the grubs stored for food by *O. spinipes*, while *C. bidentata* sucks the life out of the larvæ of the wasp itself. *C. ignita* preys upon many species, including *O. parietinus*, *spinipes* and *antilope*.

Odynerus, Latr.

O. spinipes, Linn.—Generally distributed in the district. *C. bidentata* and *ignita* attack its nests locally.

O. callosus, Thoms.—*quadratus*, Sm. *nec.* Pz.—Recorded only as yet from Rainhill, H.H.H.

O. parietum, Linn.—Fairly distributed.

O. pictus, Curt.—*oviventris*, Thoms.—Taken at Rock Ferry, J.T.G., and breeding in a sand quarry at Upton, near Chester, E.C.T., at Bolton, C. E. Stott, and described as "commonly distributed" by Mr. B. Cooke.

O. trimarginatus, Zett.—Sandhills at Wallasey. Also occurs inland at Chester, E.C.T., and near Manchester, on thistle, B.C.

O. trifasciatus, Oliv.—Recorded as "common in the district," by Mr. B. Cooke.

O. parietinus, Linn.—Very abundant at Delamere, E.C.T., taken at Chester, R.N., and E.C.T., near Birkenhead, J.T.G., and Hoylake.

O. sinuatus, Fab.—*bifasciatus*, Wesm.—Sparingly at Manchester and Hazlegrove, B.C.

Passing from the first great division of the Aculeata, the *Prædones,* we come to the second, the

ANTHOPHILA.

The *Anthophila,* or flower lovers, are the Bees, insects which are purely vegetable feeders in the larval state, and store up in the cells which they construct for their young, honey and pollen, delicate sustenance collected from flowers, instead of animal food, like the *Fossores* and *Diploptera.*

These Bees are for the most part solitary in habit, consisting of male and female only; but many of the solitary species, with their separate burrows, are, like some of the *Prædones,* of gregarious disposition, and form large colonies of nests in close proximity. Two genera, however, *Bombus* and *Apis,* form an exception to the majority of the *Anthophila,* and are social insects, with male, female and worker (or imperfect female); they live as large communities dwelling together in one nest.

Further, certain genera of the *Anthophila* form an exception to the rule of the parent providing food for her future offspring; for the inquiline or "cuckoo bees" of the genus *Nomoda, Sphecodes? Epeolus, Melecta, Cœlioxys* and *Stelis,* instead of themselves excavating burrows and storing up food therein for their future young, lay their eggs in the already provisioned nests of other species, or even, in the case of *Psithyrus,* make the workers in the nests of their social hosts feed their offspring for them.

Obtusilingues.

Bees with short flat double lobed tongues like the Wasps; these they use for lining the inside of the cells which they construct for their offspring.

COLLETIDÆ.

Colletes, Latr.—Solitary bees which burrow, frequently in large colonies, either in sandy banks (*C. daviesana* and *cunicularia*), in the softer parts of mud walls, or similar situations. Their little tunnels are usually straight, from six to ten inches long, with a series of cells opening therefrom. The cells are lined by the female bee with a delicate and glistening membrane, something like goldbeaters' skin; each contains an egg, and sufficient honey and pollen, mixed into a little cake, for the nourishment of the future grub, which the parent bee herself never lives to see.

Colletes is sometimes attacked by another bee of the inquiline genus *Epeolus*. This robber lays its eggs in the carefully excavated and provisioned cells of its host; and these eggs, hatching first, produce grubs which consume the food stored up by the *Colletes* for her offspring, thus causing the latter to perish. The grubs of the Hymenopteron *Chrysis ignita* sometimes devour the larvæ of the bee, and so do those of the little Chalcid *Monodontomerus*. Among the Diptera, *Miltogramma punctatus* feeds upon the larvæ of *Colletes*, and various *Forficulæ* are often very destructive to them. Another enemy, on the Continent, at any rate, is that curious Coleopteron *Sitaris colletis*, the larva of which, going through remarkable transformations, devours first the egg of the bee and then the honey stored in the cell.

C. succincta, Linn.—Occurs inland with us, where heather grows, as at Delamere, B.C. and R.N., at

Frodsham, J.R.H., and at Simmonswood Moss, Dr. Cotton.

C. fodiens, Kirb.—This coast species has been taken at Southport, B.C.

C. marginata, Sm.—*balteata*, Nyl., Thoms.—Wallasey sandhills, H.H.H.

C. Daviesana, Sm.—Burrows in sandstone near Wallasey village, J.T.G., by the banks of the Mersey, near Manchester, and beside the Bollin river, near Bowden, J.R.H.

C. cunicularia, Linn.—This is one of the specially interesting Bees of our district, the species being peculiar to it as far as the British Islands are concerned. The first known capture was on the Wallasey sandhills on the 4th of May, 1855, by the Rev. H. H. Higgins, who, however, only noted it in his private diary. In 1867 several specimens of the bee were taken at the same place by Mr. N. Cooke, brother to Mr. Benjamin Cooke; the fact of the discovery of this addition to our British fauna by Mr. Cooke was announced by Mr. F. Smith in "Ent. Mon. Mag.," 1869, p. 276; but, owing to the specimens having been inadvertently transferred to a box containing some Isle of Wight captures, the locality was recorded as Ventnor. In 1870 Mr. Cooke found further examples of the bees at their burrows at Wallasey, v. "Ent. Ann.," 1870. From that time to the present the insect has been taken freely in the same locality, where it is in fact abundant, making its burrows gregariously in various parts of the sandhills. It has also since been discovered to have a much more extended range in our two counties than was at first supposed. On the opposite side of the Mersey it occurs freely along the Lancashire coast, *e.g.*, near the Waterloo Coursing grounds, among the sandhills at Crosby, and at Southport, B.C., while it has been taken as far north as Blackpool by Mr. C. E. Stott. South of its "metropolis" at Wallasey, its range extends along the sandhills in Cheshire as far as Hoylake, where there is a large colony, and West Kirby, while inland a specimen has been taken near Rock Ferry, J. T. G., and another fifteen miles away from the coast, near Chester, E. C. T. Whether the two last-named captures represent distant wanderers from their seaside homes or belong to as yet undiscovered colonies located at these inland stations, has not yet been determined. On the Continent, however, the insect has a wide range inland as well as along the coast line. *C. cunicularia* is a large, handsome species, the female about the size of, and much resembling, a honey bee when on the wing; even when hovering over the sallow bloom which it loves, however, it may easily be distinguished from the latter species by its thinner legs; in the honey bee the broad flat hind legs hang conspicuously below the abdomen in flight, identifying it at once; if our *Colletes* be captured and examined, moreover, it will be found to have a broad, short, double-lobed, flat tongue, like that of a wasp, instead of the long pointed tongue of the honey bee; *C. cunicularia* is, in fact, the only British bee of large size which has a tongue of this description. *Sphecodes pilifrons* has been observed frequenting its burrows, R.N., and is possibly inquiline upon it.

Prosopis, Fab.—The females of this genus generally excavate little tunnels and cells in the stems of bramble, wild rose, dock, &c. These they line inside with a membrane somewhat after the manner of the last genus. One species, however, sometimes adopts crevices in old walls for its nest cells. They are not usually gregarious in their nidification. The food stored for their young is semi-liquid honey, as they have practically no pollen collecting apparatus. They have an enemy in a small Chalcid, which attacks and devours their larvæ.

P. communis, Nyl.—*annulata*, Kirb.—Only noted as yet from Hough End Clough, near Manchester, J.R.H.

P. signata, Panz.—Also only reported so far from the banks of the Mersey, near Manchester, J.R.H.

P. hyalinata, Sm.—*armillatus*, Nyl., Thoms.—Wallasey, breeding in mortar of old wall. Taken on the Cheshire coast, B.C.

P. confusa, Nyl.—*punctulatissima*, Sm. ♂.—Rock Ferry, J.T.G., and Southport, J.R.H.

P. pictipes, Nyl.—*varipes*, Sm.—Recorded from the banks of the Bollin, J.R.H.

Acutilingues.

Bees with narrow pointed tongues quite different from those of the last two genera, varying greatly in length.

Andrenidæ.

Halictus, Latr.—The burrows of the members of this genus of solitary bees are excavated either in sandy banks, in flat ground, or sometimes in the mortar of old walls. Each little tunnel usually branches out into several smaller ones. The entrances are usually most accurate circles, which makes the work of bees of this genus distinguishable. The interior of the tunnels is beautifully smoothed. The females, of some species at any rate, work at their excavations by night, and devote the day to collecting honey and pollen for storage in the cells as well as to rest from their labours. Most of the species are gregarious, but a few dwell apart from their fellows.

Bees are creatures with many enemies always ready to decimate their ranks. In some places the *Halicti* are much preyed upon by a solitary wasp, *Cerceris ornata*, which stings the bees and stores them as food in its own nest; but luckily for the *Halicti* of our own neighbourhood this wasp does not appear to occur here. Of other foes the female of an *Halictophagus*, one of the curious aberrant Coleoptera related to *Stylops*, to be referred to under *Andrena*, sometimes makes its home in the abdomen of *Halictus*. The burrows of this genus are occasionally frequented by bees of the genus *Nomada*, to be noted later, which are perhaps inquiline upon them. This may probably also be said of the allied genus *Sphecodes*, which associates largely with *Halictus*, and of the ant *Myrmosa melanocephala*. A Chrysid, *Hedychrum*, also preys upon the larvæ of *Halictus*. Of Diptera, various species, such as of the genus *Phorbia*, &c., haunt the nests of *Halicti*, and their carnivorous larvæ probably prey upon the grubs of the bees.

H. rubicundus, Chr.—Generally distributed over the district.

H. leucozonius, Schr.—Noted at Marple, J.R.H., Oxton, J.T.G., and as "well distributed," B.C.

H. quadrinotatus, Kerb.—Reported from West Kirby, on *Rosa spinosissima*, J.R.H.

H. lævigatus, Kirb.—*lugubris*, Kirk. ♂.—This scarce species has been taken at Hazlegrove, B.C., and at Rock Ferry, J.T.G.

H. cylindricus, Fab.—*fulvocincta*, Kirb.—Common and widespread.

H. albipes, Kirb.—*obovata*, Kirb.—Probably equally common. Specially noted at Stretford, J.R.H., Delamere and Chester, E.C.T., Rock Ferry, J.T.G., and Rainhill, H.H.H.

H. villosulus, Kirb.—*punctulatus*, Thoms.—Only observed so far at Hazlegrove, B.C., and at Rock Ferry, J.T.G.

H. atricornis, Sm.—This is another special bee in our local list. The species, when first discovered by the late Mr. B. Cooke at Hazlegrove, near Manchester, in July, 1866, was new to science, v. "Ent. Ann.," 1870, p. 26. It was subsequently obtained at the same place in some numbers by Mr. Cooke. Since then this interesting little bee has been taken by Mr. John Ray Hardy at Stretford, near Manchester; and the Rev. F. D. Morice met with it in a sand-pit at Whalley, in Lancashire. More recently it has been found in other parts of the country: in Warwickshire, both at Rugby and near Birmingham, and also in Gloucestershire, at Wotton-under-Edge; but it has not yet been discovered out of England. Both our Hazlegrove and Stretford localities have unfortunately been destroyed by building. *H. atricornis* is much like the common *H. nitidiusculus* or the less abundant *H. minutus* in outward appearance; but it is fractionally larger than *H. minutus*, and has a longer face; structurally, however, the males are easily distinguishable from all other *Halicti* by the form of the genitalia; in *H. atricornis* the apex of each of the stipites is produced into a narrow elongated stalk with a knob at its end, in a way which easily separates it from any other species, and ensures it accurate identification upon examination with a lens. The hybernated females of this bee appear in May, and males and females emerge in August and September, when they frequent flowers of the blackberry; Mr. Cooke used to take the males as early as July, or about three weeks sooner than those of the allied *H. minutus*. The burrows are excavated gregariously, generally in banks at the sides of ditches.

H. minutus, Kirb.—Pretty generally distributed, as Chorlton and Bollin Valley, J.R.H., near Manchester, B.C., Rainhill, H.H.H., Rock Ferry, J.T.G., Wallasey and Hoylake.

H. nitidiusculus, Kirb.—Also frequent over the district. *Chrysis ignita* observed to frequent its burrows.

H. minutissimus, Kirb.—Taken at Rainhill, H.H.H., and Oxton, J.T.G. Probably overlooked elsewhere.

H. tumulorum, Linn.—*flavipes*, Kirb., Sm.—Only recorded as yet from Bowden, B.C., and Rock Ferry, J.T.G., but probably only requires searching for.

H. Smeathmanellus, Kirb.—So far only noted from Delamere, R.N., but this species again is probably overlooked, as it is abundant in North Wales.

H. morio, Fab.—*æratus*, Kirb.—Another common species which has escaped observation, as our only records are from Hazlegrove, B.C., and Lindow Common, near Manchester, J.R.H.

H. leucopus, Kirb.—Taken frequently at Chester, E.C.T.

Sphecodes, Latr.—A genus nearly related to the last-named, and about the habits of which there has been much discussion. On the one hand it is held that the female excavates a nest for herself and provisions the same for her offspring like any ordinary solitary bee. On the other, it is represented that *Sphecodes* does not work, but is inquiline upon other bees. There is no doubt that *Sphecodes* associates very persistently with bees of the genus *Halictus*, and also sometimes with species of *Andrena* and *Colletes*. Examples of this mutual connection are as follows, viz.:—

S. gibbus	with	*H. rubicundus* and other *Halicti*.
S. reticulatus	,,	*H. prasinus*.
S. subquadratus	,,	various *Halicti* and *A. fulvicrus*.
S. spinulosus	,,	*H. xanthopus* and *A. fulvicrus ?*
S. punctipes	,,	*H. villosulus ?*
S. longulus	,,	*H. minutissimus*.
S. rubicundus	,,	*A. labialis*.
S. pilifrons	,,	*H. leucozonius*, *A. humilis* and *C. cunicularia*.
S. similis	,,	*H. quadrinotatus and A. fulvicrus*.
S. affinis	,,	*H. nitidiusculus*, *H. tumulorum and A. fulvicrus*.

The evidence in favour of inquilinism of this genus is based upon general analogy, upon the usual demeanour of the insect, upon the time of appearance of imago, and the habit of hybernation of same after the manner of *Halictus.* The whole question is admirably dealt with by the Rev. F. D. Morice in "Ent. Mon. Mag.," March-April, 1901, from which the above summary is taken.

S. gibbus, Linn.—Fairly distributed; specially noted about Manchester, J.R.H., and Rock Ferry, J.T.G.

S. subquadratus, Sm.—Only recorded so far from Upton, near Chester, E.C.T.

S. pilifrons, Thoms.—*rufiventris,* Sm.—Taken at Hazlegrove and at Southport, B.C.; freely upon the sandhills at Wallasey; at Chester, R.N. and E.C.T., and at Ince, R.N.; near Malpas. Three specimens observed entering burrows of *Colletes cunicularia* at Wallasey, R.N. (*v.* Ent. Mon. Mag., May, 1901).

[*S. epphippia,* Linn.—Widely distributed, as Rainhill, H.H.H., Bowden, B.C., Chester and Delamere, E.C.T., Bebington, J.T.G.]

S. affinis, v. Hag.—Hoylake; Chester, E.C.T.

Andrena, Fab.—The females of this large genus burrow eight to twelve inches deep in various situations; some in vertical banks, some in sloping undulations, and others in level ground and even in hard trodden pathways. The tunnels branch out below the entrance, and are usually but very roughly made, in contradistinction to the well smoothed burrows of the genus *Halictus.* Most of the species are gregarious, such as *A. fulva, nigroœnea, fulvicrus, albicrus,* *labialis*, and *coitana*, while a few make their little tunnels apart.

The Andrenas, like other *Anthophila*, have many foes. The bees themselves are sometimes preyed upon by rapacious Aculeates of the two genera *Vespa* and *Cerceris*, which carry them off as food for their young. Of other enemies, the writer has occasionally detected the minute orange as well as the black primary larvæ of the parasitic Coleoptera of the curious genus *Meloë* upon bees of this genus, and the imagines of one species (*M. proscarabœus*) may often be seen crawling about sandy banks near the burrows of Andrenas in our district. The apterous female of that remarkable aberrant Coleopteron *Stylops melittæ* sometimes occurs in our neighbourhood, protruding its head between the segments of the abdomen of individuals of certain species of the genus *Andrena*, and causing curious malformation in the bee; but the writer has never met with the rare male, nor has Mr. R. Newstead, who has kept special watch for it; the Rev. H. H. Higgins once secured one of these exquisitely graceful white winged flies in his garden at Rainhill. The nests of *Andrena* are much attacked by bees of the inquiline genus *Nomada*, whose larvæ appropriate the honey and pollen cakes stored up by their hosts, as noted more particularly later; and a small Dipteron of the genus *Bombilius* also enters their burrows, where its carnivorous grubs devour the larvæ of the bee.

A. albicans, Kirb.—One of our commonest spring species all over the district.

A. tibialis, Kirb., *atriceps*, Kirb., Thoms, *Mouffetella*, ♂ Kirb.—So far only recorded from Sale and from Chat Moss, J.R.H.

A. Rosæ, Panz., var. *Trimmerana*, Kirb.—Abundant and widespread in the district.

A. cineraria, Linn.—This handsome species has been taken at Hough End Clough, near Manchester, J.R.H., Rainhill, H.H.H., High Leigh and Ince, R.N., Chester, a colony at Bache Hall, E.C.T., and variously in the district, B.C.

A. thoracica, Fab.Only recorded from Rock Ferry, J.T.G.

A. nitida, Fourc.—Willaston, J.T.G., Disley, C. E. Stott, and described as "widely distributed" in the district, B.C.

A. fulva, Schr.—This pretty bee is well distributed in the district, burrowing in paths, grassy commons and garden lawns. It is a species that is particularly variable in its occurrence hereabouts, being sometimes scarce, while in other years it has appeared in phenomenal abundance. In 1898 and 1899, for instance, *A. fulva* literally swarmed in many localities. Grass plots in gardens were riddled with its burrows, their surrounding little heaps of sand looking like innumerable mole hills in miniature, while the brilliantly coloured bees sat on nearly every daisy, to the no small astonishment of the owners of the lawns. Such was the case in a garden at Knotty Ash, on a common at Oxton and at Nantwich; around Manchester, in gardens at Cheetham Hill, Didsbury, Ashton and Barton, and on Lindow Common (where with accompanying swarms of *Meloë proscarabæus* about burrows) the same phenomenon was noted, J.R.H.; also at Chester, R.N. These years of special abundance of insects in our district are as yet difficult to account for fully. Among the Coleoptera, *C. hybrida* and many *Hydradephaga* may be mentioned as swarming, and the rare *Ægalia rufa* as specially abundant, some seasons, and as again hardly visible for years. Among the Lepidoptera the same has been noted of *C. Edusa*, of the occasional plague *C. graminis*, and of the notorious *D. galii* (the latter ably treated of by Mr. W. E. Sharp in a paper in Trans., Liverpool Biol. Socy., vol. VII., p. 17). It is probable that the periodical abundance of *A. fulva* is largely due to the weather during the breeding season of both itself and of its several enemies. It is certainly not explainable by the favourite "blown over from the Continent" theory of the Lepidopterist.

A. Clarkella, Kirb.—Usually our first spring bee; has been specially noted near Manchester and at Bowden, B.C.; Delamere, B.C. and E.C.T.; Rainhill, H.H.H.; Wallasey sandhills and Ledsham.

A. nigroœnea, Kirb.—*aprilina*, Sm.—Abundant and widely distributed over our two counties.

A. Gwynana, Kirb. (1st brood).—*bicolor*, Fab. (2nd brood).—Only reported so far from Hazlegrove, B.C., and Rainhill, H.H.H., but probably occurs elsewhere, as it is common in North Wales.

A. angustior, Kirb.—A scarce insect taken at Hazlegrove, B.C.

A. varians, Rossi.—Has occurred at Wallasey and Chester, E.C.T., and at Rock Ferry, J.T.G.

A. helvola, Linn.—Reported from Hazlegrove, B.C., Rainhill, H.H.H., and Rock Ferry, J.T.G.

A. fucata, Sm.—Taken on Wallasey sandhills.

A. nigriceps, Kirb., Sm.—This scarce species has been taken at Rock Ferry, J.T.G.

A. fulvicrus, Kirb.—*extricata*, Sm.—Taken at Rainhill, H.H.H., and Rock Ferry, J.T.G. "Near Liverpool" is mentioned as a locality in Smith's "British Bees," second edition, p. 58.

A. albicrus, Kirb.—A very common species with us both on our coasts and inland.

A. analis, Panz.—Once taken at Rock Ferry, J.T.G.

A. humilis, Imh.—*fulvescens*, Sm.—Has occurred near Manchester, B.C.; and at Rock Ferry, J.T.G.

A. labialis, Kirb.—*separata*, Sm.—Taken at Hazlegrove, B.C., Bollin Valley, Eccles and Lindow, J.R.H., and Rock Ferry, J.T.G.

A. minutula, Kirb. (2nd brood).—*parvula*, Kirb. (1st brood).—Only recorded so far from Crosby and Rainhill, H.H.H.

A. nana, Kirb.—Noted as yet only from Bowden and Hazlegrove, B.C.

A. Wilkella, Kirb.—*xanthura*, Kirb.—Bowden and Hazlegrove, B.C., Chester, E.C.T.

Cilissa, Leach.—This genus contains only three species in Britain. Their habits are probably the same as the gregarious members of the genus *Andrena*. They have not, so far, been recorded in our district, though *C. leporina* may exist, as it occurs in North Wales.

Dasypoda, Latr.—Our single and striking British species burrows in large colonies in sandhills, generally choosing a bank overgrown with herbage, and with a southern aspect. One little tunnel leads to a series of cells, and all are very roughly finished internally.

This genus does not seem to be a prey to any inquiline bees, but it has an enemy in a small Dipteron of the genus *Miltogramma*, whose grubs nourish themselves at the expense of the larvæ of the bee.

D. hirtipes.—Latr.—Along Cheshire coast, B.C. Formerly very abundant on Wallasey sandhills, but apparently not there now. Inland at Sale and valley of the Bollin, J.R.H.

Macropis, Panz.—The single British species of this genus has only been taken in the South of England, and is unlikely to occur in our district.

Panurgus, Panz.—Our two British species burrow gregariously in sandy banks or sometimes in hard trodden pathways. They have not hitherto been observed in our district, though *P. ursines* occurs not far off in North Wales.

The latter species is sometimes attacked by the inquiline *Nomada fabriciana*, and the Dipteron *Miltogramma punctata* preys upon the larvæ of *Panurgus*.

Dufourea, Lep.—This genus contains but one species in Britain, which is very rare. Nothing appears to be known of its habits.

Rophites, Spin.—Another genus with only one species, to which the above remarks equally apply.

Nomada, Fab.—This is a genus of inquiline or, as they are frequently called, "cuckoo bees." These wasp-like looking insects, instead of excavating burrows and storing up food for their offspring therein themselves, like other Aculeates, simply appropriate the results of the toil of other bees, and lay their eggs in the carefully constructed and well victualled cells of various industrious species. Their hosts are bees of the genus *Andrena*, *Halictus*, *Eucera* and *Panurgus*, none of which the bright "warning colours" of *Nomada* in the least resemble. The flight of the species of this genus, as of other inquilines, is slow, listless and silent, quite different from the quick energetic activity and busy hum of an industrious bee.

The *Nomadæ* are sometimes particular but often promiscuous in their inquilinism. So far as observation by various authorities has gone, however, the following species appear to associate themselves with the under-mentioned hosts, viz.:

N. Robertjeotiana	with	*Andrena analis* and *? Halictus rubicundus.*
N. solidaginis -	,,	*Andrena nigriceps* and *? Halictus leucozonius.*
N. fucata - -	,,	*Andrena fulvicrus, ? Halictus rubicundus,* and *? Halictus leucozonius.*
N. sexfasciata -	,,	*Eucera longicornis.*
N. alternata -	,,	*Andrena atriceps, Andrena nigro-ænea* and *Andrena albicans.*
N. jacobææ - -	,,	*Andrena fulvicrus.*
N. Lathburiana -	,,	*Andrena labialis* and *Andrena fulva.*
N. albogutata -	,,	*Andrena argentata.*
N. ruficornis -	,,	*Andrena Trimerana, Andrena atriceps, Andrena fulva and Andrena nigro-ænea.*
N. bifida - -	,,	*Andrena albicans.*
N. borealis - -	,,	*Andrena Clarkella.*
N. lateralis - -	,,	*Andrena bucephala.*

N. ochrostoma	-	with	*Andrena labialis* and *Andrena wilkella.*
N. armata -	-	„	*Andrena Hattorfiana.*
N. ferruginata	-	„	*Andrena fulvescens, Andrena humilis and Andrena Cetii.*
N. fabriciana	-	„	*Andrena gwynana* and *Panurgus ursines.*
N. flavoguttata	-	„	*Andrena wilkella* probably, and *Andrena nana.*
N. furva -	-	„	*? Halictus morio, ? Halictus minutus and ? Halictus nitidiusculus.*

N.B.--Though certain species of *Nomada* associate with species of *Halictus,* whether they are really inquiline in their cells is apparently still undecided.

N. solidaginis, Panz.—Taken at Rock Ferry, J.T.G.

N. succincta, Panz.—Common and widely distributed in the district.

N. jacobææ, Panz.—Taken in valley of the Bollin, J.R.H., and sparingly near Chester, R.N.

N. alternata, Kirb.—*Marshamella,* Kirb., Thoms.—Equally abundant and widespread with *succincta.* Specially observed at burrows of *A. albicans,* E.C.T.

N. Lathburiana, Kirb.—*rufiventris,* Kirb., Thoms.—This local species has been taken near Manchester, B.C., and at Bache Hall, Chester, "at burrows of *A. fulva,*" E.C.T.

N. lateralis, Panz. *nec* Sm.—*xanthosticta,* Kirb., Sm. —Reported from near Manchester, B.C., and from banks of the Mersey at Chorlton, J.R.H.

N borealis, Zett.—Rivington, B.C., Bolton, C. E. Stott;

and "taken in the Wirral," H.H.H. It is not infrequent in North Wales.

N. ruficornis, Linn.—Valley of the Bollin, J.R.H., "in the Wirral," H.H.H. Chester, common locally, E.C.T., Wallasey, H. Locke, and described as "fairly distributed," B.C. This species varies much in colour locally.

N. ochostroma, Kirk.—*punctiscuta*, Thoms.—Taken at Hazlegrove, B.C.

N. ferruginata, Kirb.—*germanica*, Sm.—Reported from Stretford and Bowden, J.R.H.

N. Fabriciana, Linn.—Stretford and Eccles, J.R.H., Rainhill, H.H.H., Chester, E.C.T., and "fairly distributed over the district," B.C.

N. furva, Panz.—Only recorded so far from valley of the Bollin, J.R.H.

Apidæ.

Epeolus, Latr.—This genus is inquiline in habit, like *Nomada*. It attaches itself to bees of the genus *Colletes*, and has also been taken in association with *Megachile argentata*.

E. productus, Thoms.—*variegata*, *pars.*, Sm.—Taken in the valley of the Bollin and at Sale, J.R.H.; Hoylake, E.C.T., and West Kirby, J.R.H.

Ceratina, Latr.—Our one small British species excavates its cells in dead bramble stalks. It is rare, and has not been observed in this district.

Chelostoma, Latr.—The members of this genus are called "Carpenter Bees." They usually drill holes in wooden posts, though they sometimes choose ready-made cavities, such as straws in thatch. *Chrysis cyanea* is parasitical upon *Chelostoma*.

C. florisomne, Linn.—Rainhill, H.H.H.

Heriades, Spin.—This genus contains but one species, of habits similar to *Chelostoma*. It is very rare in Britain.

Cœlioxys, Latr.—Another inquiline genus, usually laying its eggs in the previously excavated and provisioned cells of *Megachile*, to which it is structurally nearly related. It also attacks *Osmia*, *Anthophora* (on the Continent) and *Saropoda*. Most of the species appear to be more or less promiscuous (always within the limits of the above genera) in choice of hosts. Our British examples of the genus have, however, been specially noticed to associate with the following, viz.:—

C. vectis	with	*Megachile maritima.*
C. rufescens	,,	*M. circumcincta* and *Osmia xanthomelana.*
C. elongata	,,	*M. lignesceca, M. willughbiella, M. circumcincta,* and *Osmia rufa.*

Upon the Continent, at any rate, the parasitical *Cœlioxys* is in its turn preyed upon by the Dipteron *Anthrax*, whose grubs devour its larvæ; and both *Cœlioxys* and *Anthrax* again are further attacked by the little Chalcid *Monodontomerus*, whose grubs are nourished at the expense of the flesh and blood of its hosts.

C. quadridentata, L.—*conica*, Thoms.—Reported as numerous at Formby, H.H.H.

C. elongata, Lep.—*symplex*, Nyl., Thoms.—Widely distributed in our district. Specially noted at Leasowe; along the Cheshire coast, and at Southport, B.C.; Formby, H.H.H.; Higher Bebington, J.T.G.; Ince, R.N.; Delamere, associated with a colony of *M. willughbiella,* E.C.T. and R.N.

C. acuminata, Nyl.—Once taken on sandhills at Wallasey.

C. mandibularis, Nyl.—This is another notable bee in our local list. A single specimen was taken among the sandhills at Wallasey in July, 1900, by Mr. F. Birch, being the first and only time that the insect has occurred in Great Britain, *v.* "Ent. Mon. Mag.," July, 1901, p. 166-167. This *Cœlioxys* is probably inquiline upon some species of the genus *Megachile,* colonies of which should be watched in our district; but although the bee is fairly distributed upon the Continent, its actual host has not yet been discovered. It is to be hoped that further examples may be found at Wallasey, and that the life history of the species may be worked out there.

From other members of the genus *C. mandibularis* may be distinguished best by the form of its mandibles; these are produced into a distinct angle near the centre of the anterior side, just above the base of the apical groove. To see this fully the insect should be turned on its back and the mandibles examined from behind. There are also various other minor points of difference.

Megachile, Latr.—These bees, whose cleverly constructed cells have long been the admiration of naturalists, are popularly known as "Leaf Cutters." They burrow gregariously in various situations, *e.g.*, in decayed wood (*M. centuncularis, willughbiella, lignesceca* and *versicolor*), in sandy ground (*M. centuncularis, circumcinta, maritima, argentata* and *versicolor*), in the mortar of old walls (*M. centuncularis M. maritima*), and in sound oak and mountain ash trees (*M. lignesceca*). Most of the species, however, do not strictly confine themselves to the above situations for nidification. The little tunnels thus excavated they line in a remarkable and beautiful manner with pieces of leaves or flowers most accurately cut to the required size and shape from various trees and shrubs, chosen more or less according to species. No one "Leaf cutter," however, confines itself to one particular kind of plant, though the undermentioned have been observed to be selected most frequently by the following species, viz.:—

Rose - - -	by	*M. centuncularis, circumcinta*, and *willughbiella*.
Mercury - -	,,	*M. centuncularis* and *circumcinta*.
Laburnum - -	,,	*M. centuncularis* and *willughbiella*.
Lilac - - -	,,	*M. centuncularis*.
Sallow - - -	,,	*M. centuncularis* and *maritima*.
Buckthorn - -	,,	*M. circumcinta*.
Scarlet geranium petals	,,	*M. centuncularis*.
Lotus corniculata petals	,,	*M. argentata*.

The nests of the leaf-cutting bees are attacked by the inquiline and nearly-related genus *Cœlioxys*, and also by the Chalcid *Monodontomerus*.

M. maritima, Kirb.—*lagopoda*, Thoms.—Wallasey sandhills; the Cheshire coast, B.C.; not infrequent in North Wales.

M. Willughbiella, Kirb.—Fairly distributed, as Bowden, B.C.; near Birkenhead, J.T.G.; Chester, on flowers of sweet pea, E.C.T. and R.N.; Delamere, E.C.T. and R.N. *Monodontomerus æneus* ? bred from nest cells at Chester, R.N.

M. circumcincta, Lep.—Pretty frequent in our district, both on the coast and inland. Taken on sandhills at Hoylake and Wallasey; and at Southport, B.C. Inland, it has occurred at Poolton; Rock Ferry, J.T.G.; near Birkenhead, H.H.H.; Chester, where a colony was found behind garden steps within the city, R.N.; and Delamere, E.C.T.

M. centuncularis, Linn.—Fairly common and widespread both on our coasts and inland.

Osmia, Panz.—The bees of this genus are called "Mason Bees" from the marvellous way in which they construct their cells of a cement formed of grains of sand, small stones, &c., agglutinated together by a secretion of the insect. These cells are constructed in widely different situations by the various species, and with an extraordinary power of adaptability to circumstances. *O. cærulescens, rufa, bicolor* and *aurulenta* generally adopt any ready-made burrows in sandy banks, old mud walls or dead wood. *O. fulviventris* usually selects the latter situation. *O. leucomelana* forms a nidus in dead bramble stalks, *O. parietina* makes its nest in cavities in stones and rocks, *O. inermis* clusters its cocoons under flat stones, while *O. xanthomelana* constructs its beautiful little pitcher-shaped cells at the roots of grass. Some species, such as *O. rufa, bicolor* and *aurulenta*, occasionally adopt almost any available cavity; they construct their cells inside straws and reeds, in deserted snail shells, or sometimes even instal themselves in keyholes. *O. bicolor*, when nesting in snail shells, has the curious habit of covering the shell with a pile of stalks, &c., making it look like an ants' nest in miniature. Several of the species are gregarious, forming large colonies.

The nests of *Osmia* are attacked by inquiline bees of the genus *Stelis*, and sometimes by *Cœlioxys*. Certain *Chrysididæ* and *Monodontomerus dentipes* also prey upon the larvæ of *Osmia*.

O. rufa, Linn.—Fairly common; specially noted at Hoylake, West Kirby, and Oxton; Cheshire coast, B.C.; Chester, E.C.T.; Bowden, J.R.H.; Rainhill, H.H.H.

O. xanthomelana, Kirb.—*fusciformis*, Gerst, *nec* Sm.—*atricapilla*, Curt.—This rare species was taken in tolerable abundance upon a "perpendicular bank by the riverside, near Liverpool," in 1835, by Mr. G. R. Waterhouse, and its interesting life history worked out, *v.* "Zoologist," Vol. II., p. 403. The female makes a nest composed of from three to six beautifully constructed pitcher-shaped cells of mud and grit and closed with lids, which she usually places in light dry soil at the roots of grass; sometimes the cells are partly exposed, while occasionally they are in a little chamber underground. The imago frequents *Lotus corniculatus*.

None of our recent collectors have been able to discover this species near Liverpool. Its old habitat of 1835 has probably long been destroyed by building. The writer has taken it, under conditions similar to those described by Mr. Waterhouse, at two localities in North Wales. The male emerges in May (Mr. W. once took an example in March), and the female occurs in May, June and even in July.

O. cærulescens, Linn.—*ænea*, Sm.—Pretty frequent along the Cheshire coast, B.C.; Wallasey, E.C.T.; Rock Ferry, J.T.G.; Chester, E.C.T. and R.N.; Delamere, E.C.T.

O. fulviventris, Panz.—Has been taken at Crosby, H.H.H.; Rock Ferry, J.T.G., and Wallasey, E.C.T.

O. aurulenta, Panz.—Taken freely breeding in snail shells on the sandhills at Wallasey in 1855, H.H.H.; and similarly by Mr. J. T. Carrington some years afterwards; but search has been made for it in vain during recent years.*

Stelis, Panz.—The three species found in Britain are inquiline in the burrows of the genus *Osmia*, though in other countries they attack *Anthidium*, to which genus *Stelis* is very closely related. *S. phæoptera* and *aterrimma* are associated with *O. fulviventris*, and the rare *S. octomaculata* with *O. leucomelana*. None of the species have yet been recorded in our district, though some probably occur. *S. aterrimma* is not infrequent just outside our limits on the North Wales coast.

Anthidium, Fab.—Our one distinct looking British species makes its cells in suitable holes which it may find ready-made, such as the larval burrows of *Cossus ligniperdi* or of *Aromia moschata*; these the female lines with down, which she collects

* Since these pages went to the press, the writer has turned up the species again at Wallasey, frequenting flowers of the bramble.

from plants with woolly leaves, such as *Stachys*, *Ballota* or *Lychnis*.

No inquiline species seems yet to have been associated with this bee in Britain, though a watch might be kept upon *Stelis*. *Monodontomerus* attacks it.

A. manicatum, Linn.—Recorded so far only from valley of the Bollin, J.R.H., and Rainhill, H.H.H. though it probably occurs elsewhere, as it is abundant in North Wales.

Eucera, Scop.—The single species of this genus, *E. longicornis*, burrows about eight inches deep in the ground, and usually forms large colonies where it occurs. It has not yet been observed in our district.

Melecta, Latr.—An inquiline genus containing two species in Britain associated with *Anthophora*, to which it is zoologically nearly related. *M. luctuosa* attacks *A. retusa*, and *M. armata* apparently preys upon both *A. retusa* and *A. pilipes*. Unlike the inquiline *Nomadæ* and their hosts the *Andrenæ*, between whom no enmity is apparent, the *Melectæ* sometimes attack and fight for very life with the *Anthophoræ* whose nests and food stores they endeavour to appropriate. These inquilines have never yet been observed in our district, but they should be sought for, as one of their hosts, *A. pilipes*, is abundant. Curiously, however, *M. armata* is very seldom seen in North Wales, though *A. pilipes* swarms in some places there.

The parasitical *Melecta* is in its turn attacked by enemies, including the larvæ of the Dipteron *Anthrax*, on the Continent, at any rate, and the

Chalcid *Monodontomerus*. The primary larvæ of *Meloë* sometimes infest these bees.

Anthophora, Latr.—A genus containing four species in Britain, three of which, *A. retusa, pilipes* and *quadrimaculata*, burrow in hard sand, mud banks or mortar of walls, and the fourth, *A. furcata*, in decayed wood. The two first-named are gregarious. The earth-burrowing species make large oval cells, which look like rough pebbles externally; inside they are exquisitely finished, almost resembling porcelain.

These bees again have many enemies, which attack them in various ways,—the allied inquiline genera *Melecta* and *Cœlioxys*, the remarkable Coleopteron *Sitaris muralis*, Forst., the delicate Dipteron *Anthrax*, and the little Chalcid *Monodontomerus nitidus*. Sometimes only about half the cells in a colony of *Anthophora* produce offspring arriving at maturity.

A. retusa, Linn.—*Haworthiana*, Kirb.—Taken at Hazlegrove, B.C.

A. pilipes, Fab.—*acervorum*, Sm.—*retusa*, Kirb.—Distributed widely in the district, and often abundant locally. *Sitaris muralis* has been taken near its burrows in the valley of the Bollin, J.R.H.

A. furcata, Panz.—Only single specimens so far recorded, from Chester, E.C.T., and Hooton, R.N. It should occur elsewhere in Cheshire, as it is not infrequent in North Wales.

Saropoda, Latr.—The quick-flying and shrill-sounding *S. bimaculata* is the only British species. It forms large colonies in banks and sandy cliffs. Apparently a southern insect, it has not been recorded in our neighbourhood. The inquiline *Cœlioxys* is said to attack it.

Leaving the above solitary genera, with male and female only, we now come to bees which, with the exception of the inquiline *Psithyri*, are social species. They live in large communities, comprising males, females and workers, all dwelling together in one nest.

Bombus, Latr.—A genus consisting of the well-known Humble Bees. The females, aided by the workers, construct nests of moss, grass, &c., in which numbers, small or large according to the species, are reared and live. Some kinds, such as *B. terrestris*, *lapidarius* and *hortorum*, make use of ready-made cavities more or less underground; while others, as *B. venustus*, *agrorum*, *sylvarum* and *pratorum*, either build elaborate nests of moss, grass, &c., above the surface, or else adapt the old nests of ground-building birds to their use. Those species that make their nests in the ground often store up honey in considerable quantities in the waxen cells which they construct; so much so, that many small animals, such as mice, seek out the nests for purposes of plunder, and in some rural districts, especially in Scotland, the search for the nests of the red-tailed "Bumble Bee," with its sweet-tasting contents, is a recognised holiday pursuit of the village schoolboy.

Few Aculeates have more enemies than the *Bombi*. Chief among these are the allied inquiline bees of the genus *Psithyrus*; by appropriating their nests, provisions and even workers, the inquilines sometimes decimate the numbers of their hosts, as in the case of *P. vestalis* where it attacks *B. terrestris.* The carnivorous grubs of the bee-mimicking Diptera of the genus *Volucella* prey largely upon the larvæ of some of the *Bombi*, but the grubs of *Homalomyia* found in their colonies possibly act as scavengers there. Some of the solitary ants, *Mutillidæ*, live in the nests of humble bees, but whether as enemies or friends is not yet known; other ants of various species often pillage them for the sake of the honey. Many Coleoptera, chiefly *Staphylinidæ* and *Homolota*, are also found in the nests of this genus, some few breeding there; but the majority would appear to be plunderers or casual visitors. Under the same categories certain Hemiptera may be included. The larva of a Lepidopteron, *Aphomia sociella*, sometimes does great damage to the nest by devouring the waxen cells. The humble bees themselves are largely infested by an Acarid of the family *Gamasidæ*, *Pæcilœchirus fucorum*, Berl., in its nymphal form, whose larvæ also probably feed upon the wax in the nests of their hosts; they sometimes moreover become a prey to the Dipteron *Conops*, whose grubs live within their bodies and devour their viscera.

B. venustus, Sm.—*cognatus*, Saund, *nec*, Steph.—*senilis*, Sm.—*variabilis*, Schmied.—Fairly distributed, but nowhere abundant. Specially noted West Kirby, Bidston, Barnston; Higher Bebington, J.T.G.; Hooton, R.N.; Warrington, B.C.; Wallasey, E.C.T.

B. agrorum, Fab., Kirb., Smith, Schmied, Thoms.—*muscorum*, Smith, Saund.—Widely distributed and abundant. A colony in a willow-wren's nest at Barnston; another similarly near Chester, R.N.,; one in a shrewmouse's nest near Manchester, J.R.H.

B. *hortorum*, Linn.—Common and generally distributed.

B. var. *subterraneus*, Auct., *nec* Thoms. —This dark variety is frequent in our district, R.N. and B.C.

B. var. *Harrisellus*, Kirb.—This black variety also occurs here and there, as at West Kirby, J.T.G., Chester, E.C.T., Aldford, R.N., Mottram, Broad Bottom, and Chat Moss, J.R.H. Both the dark and black forms of *hortorum* have been observed to be on the increase locally during recent years, as has also been noted in the case of many of our Lepidoptera.

B. *Latreillellus*, Kirb.—*subterraneus*, Thoms.—Only noted as yet from banks of the Mersey at Stretford, J.R.H.

B. var. *distinguendus*, Mor.—*elegans*, Sm., *nec* Seidl.—*fragrans*, Auct., *nec* Pall.—This handsome variety has been taken at Lindow Common and on Chat Moss, J.R.H.; also at Delamere, E.C.T.

B. *sylvarum*, Linn.—Widespread over the district.

B. *Derhamellus*, Kirb.—*Rajellus*, Kirb., Thoms.—Not infrequent, as at Heswall and West Kirby; Chester district, E.C.T.; and probably overlooked elsewhere. The writer once captured one of these bees with no less than seven of the curious anthers of *Orchis mascula* attached to its face, for the cross-fertilization of the flower, in the manner so graphically described by Darwin in his "Fertilization of Orchids."

B. *lapidarius*, Linn.—Abundant everywhere. "Males specially partial to purple iris, females to lavender, and workers to clover," E.C.T.

Workers of *Vespa vulgaris* seen to enter a nest, probably to pillage the honey, E.C.T.

B. lapponicus, Fab.—This is an Alpine species; it occurs high up in Switzerland and in the Pyrenees, and ranges over the mountains of Norway, Scotland and North Wales. In our own district it has been taken upon the moors and hills on the borders of Lancashire, between Rochdale and Marsden, B.C.; and near Stalybridge, B.C. and J.R.H.; it is also sometimes found lower down, on the heather and peat of Chat Moss, J.R.H.

B. pratorum, Linn.—Our earliest *Bombus*, abundant everywhere. A colony in a hedge sparrow's nest at Chester, R.N.

B. terrestris, Linn.—*lucorum*, Sm.—*virginalis*, Kirb.—Common everywhere. These bees have sometimes been observed to damage bean crops by puncturing the base of the flowers and rendering the pod more or less abortive. Curtis, in his "Farm Insects," p. 351, records a case of a garden of scarlet runners being entirely destroyed in this way near Manchester.

Psithyrus, Lep.—*Apathus*, Newm.—A genus of inquiline bees attacking the nests of the nearly-related *Bombi*. These insects are heavy and listless in flight, and thus distinguishable upon the wing from their busy and active hosts. As with other inquilines, they consist of male and female only, without workers. Unlike the absolute dissimilarity between the waspish Nomadas and their hosts the Andrenas, the *Psithyri* greatly resemble in form, and in many instances also in colour, the *Bombi* whose nests they invade; and this is necessary, for instead of apparently living in amity with their hosts, as is usual with most of the inquiline bees, the female *Psithyrus*, like *Melecta*, enters the nest of her selected *Bombus* as a murderous enemy, and, as actually observed by Mr. F. W. L. Sladen (*v.* "Ent. Mon. Mag.," October, 1899), fights with and slays the owner "queen" before taking possession, or sometimes, as noted by Mons. E. Hoffer, gets killed herself. A victorious *Psithyrus* not only appropriates the nest of the conquered species, but forces the workers therein to collect food for and to rear her own progeny. The various species of *Psithyri* are usually inquiline with the following *Bombi*, viz.:—

P. rupestris	in nests of	*B. lapidarius.*
P. vestalis	,, ,,	*B. terrestris.*
P. barbutellus	,, ,,	*B. hortorum* and *pratorum.*
P. quadricolor	,, ,,	*B. pratorum* and *jonellus.*
P. campestris	,, ,,	*B. agrorum, venustus,* and *latriellellus.*

The first three resemble their hosts in colour as well as in form, while the last two only do so in the latter particular for the most part.

P. rupestris, Fab.—Only noted so far from West Kirby Thurstaston and Heswall; also Chester, E.C.T.; possibly overlooked.

P. vestalis, Fourc.—Widely distributed and often abundant, *e.g.*, West Kirby and Heswall; Southport, B.C., Chat Moss, J.R.H., Helsby, R.N., Chester, R.N. and E.C.T., Delamere, E.C.T. and R.N.

P. barbutellus, Kirb., *nec* Sm.—Frequent in the district, as Oxton and West Kirby; Rock Ferry, J.T.G.; Rainhill, H.H.H.; near Manchester, J.R.H.

P. campestris, Panz.—*Rossiellus*, Kirb., Thoms.—Wide-spread; specially noted near Manchester, J.R.H.; Knowsley, H.H.H.; Chester and Delamere, E.C.T. and R.N. Two black specimens taken at Chester, R.N.; this variety is frequent just over our borders in Staffordshire.

P. quadricolor, Lep.—*Barbutellus*, Sm.—Only records so far are one exceedingly small female taken by the writer at Bidston, and two dark varieties at Chester, E.C.T.

Apis, Linn.—The most typical social genus; it contains one species only in Britain, *A. mellifica*, the Honey Bee, whose well-known economy and intelligence makes it the most highly developed and wonderful of all bees, or perhaps of any insect. The communities of this species are very large indeed, sometimes amounting to 40,000 or 50,000 inhabitants; they consist of female or queen, males, and workers, or imperfect females; their dwellings are most complex structures, full of hexagonal waxen cells, of marvellous design and workmanship, for breeding and food-storing purposes.

A. mellifica, Linn.—Whether this species was ever wild in this country, nesting in a state of nature in cavities among rocks, in holes in trees, &c., as it still does in some parts of the world, we cannot say. Certain it is that the honey bee has been domesticated by man almost from time immemorial. The successive inhabitants of these islands, Celt, Saxon and Norman, have all kept this bee in artificial dwellings or hives, for the sake of the wax and honey stored therein by the industrious insects. For many centuries the Beemaster was a regular labourer employed upon nearly every manorial farm in England. After the Reformation, however, the demand for wax for the candles used at the Mass fell off enormously, and soon after this again the importation of sugar from the West Indies did away with one of the chief uses of honey. Thus the hives kept were fewer, and, as the culture of this valuable insect grew more and more neglected, they were gradually relegated from the fields to the herb garden, and from the farm labourer to the housewife. It is only of recent years that there has been a reaction, and the useful and profitable honey bee has come much more to the front again.

Like the other Aculeates, the honey bee has many enemies and parasites. In the imago state, like other bees, it is often devoured by birds, the culprits being the swift, the swallow, the flycatcher, the great and blue tits, the shrikes and the omnivorous sparrow (particularly in its breeding season), and sometimes the green woodpecker. The domestic duck also greedily gobbles up bees, quite regardless of their stings. Luckily the bee-eater, *Merops apiaster*, is practically absent from Britain. Such reptiles as the lizard, the toad and the frog are likewise fond of bees. Among the Aculeate Hymenoptera, several species prey upon the honey bee. Fortunately the destructive solitary wasp, *Philanthus apivorus*, which stores up bees in its burrows, does not often cross the Channel from the Continent; but our native social species, the fierce hawk-like hornet and the common wasp, attack and carry off the honey bee as food for their young. The writer has particularly observed this to be the case in years when wasps are specially abundant and food possibly scarcer; in other seasons wasps only attack the bees when weak. No species of *Stylops* seems to infest *A. mellifica*, but the young larvæ of the Coleopterous *Meloë*, previously noted in connection with *Andrena*, sometimes do serious harm by violently irritating the worker bees to which they attach themselves.

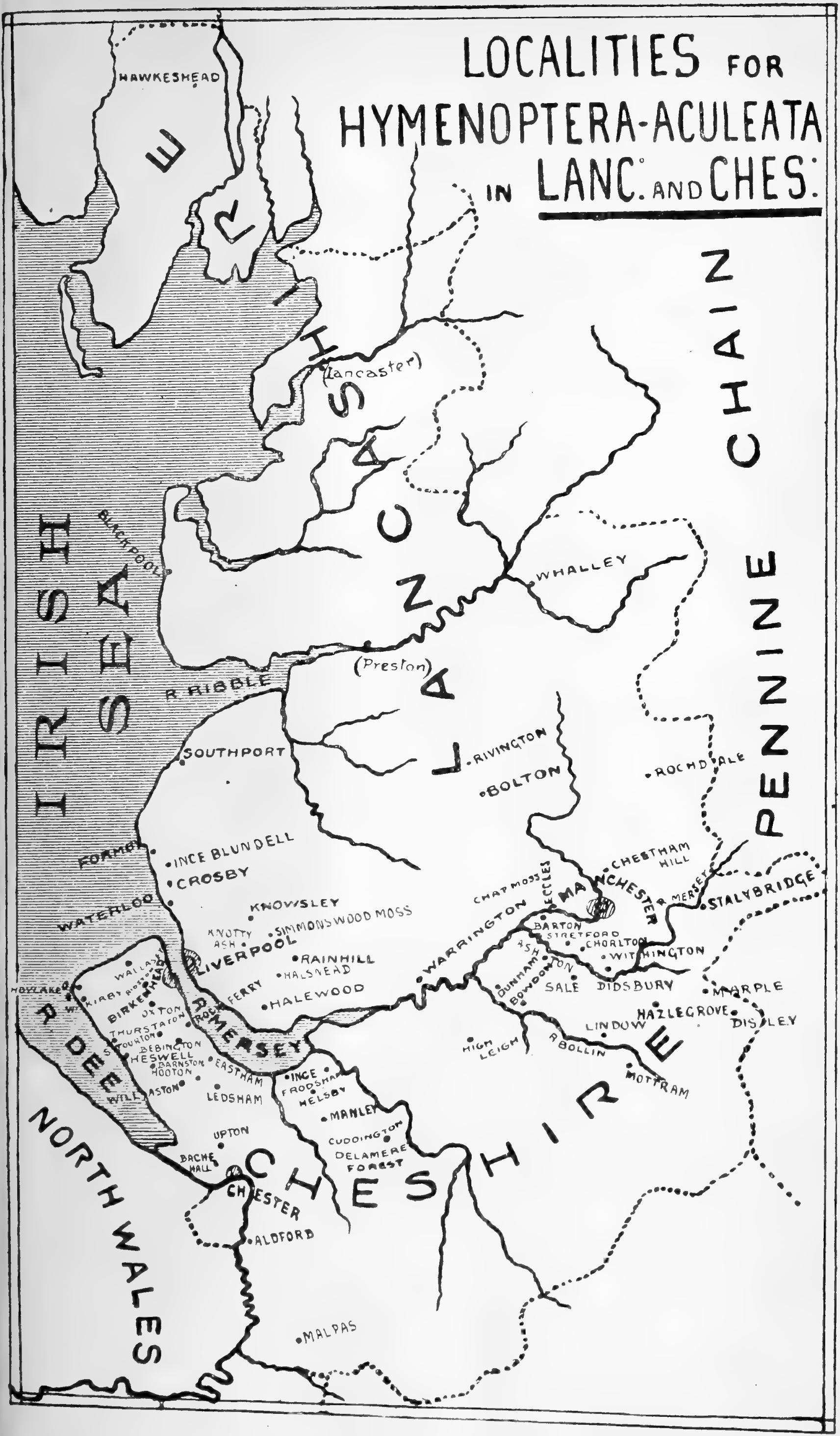
Inside the hives no inquiline bees appropriate the fruits of the labours of their hosts, as is the case with most wild bees; but the honey stored there is at times plundered by many enemies —by mice of various kinds, by robber bees from neighbouring hives, by wasps, occasionally by the large Lepidopteron *A. atropos*, by certain Coleoptera, and by ants. The combs are sometimes sadly damaged by the larvæ of two species of Lepidoptera, which live upon the wax, viz., the large Crambite, *Galleria melonella*, Linn., and the smaller *Achrœa grisella*, Fab.; but these pests, as well as most of the enemies to bees previously noted, are much less in evidence now than in the days when straw skeps were common in the district. Other occasional parasites in the hive are a small Dipteron, *Braula cœca*, imported with foreign "queens," and an *Acarus*. But of course the greatest enemy of all to the Apiarist is the dread *Bacillus* that causes what is known as "foul brood" in the combs.

Until comparatively late years the bee kept everywhere in the country was the true *A. mellifica*, commonly known as the native "black bee." Recently, however, queens and colonies of the var. *ligustica*, the bee of which Virgil wrote, have been largely imported into our district, as elsewhere in England, from Italy. In the same way the Cyprian and Carniolan races have been introduced. These foreign strains have become much mixed by inter-breeding with our primeval race, so that the native "black bee" in its original purity is in some places becoming more or less rare; it has a wonderful power, nevertheless, of asserting its individuality again, and of absorbing the foreigner in course of comparatively few generations, if left to itself.

This completes our list of the Hymenoptera-Aculeata hitherto observed in the counties of Lancashire and Cheshire. On reference to the map it will be noticed that the records are at present confined to a comparatively limited portion of our district, and there is little doubt that the investigation of new neighbourhoods will afford material additions in the future. Several easily overlooked but common species, which, though found in North Wales, have not yet been recorded here, probably also occur.

In conclusion, it may not be uninteresting to compare the above results with the two orders of insects of which faunas have up to the present been compiled for Lancashire and Cheshire, viz., Lepidoptera and Coleoptera, as follows:—

	Species recorded.				
Hymenoptera Aculeata -	166;	or 44 %	of total	British species	(374).
Lepidoptera - - -	1,355;	,, 65 %	,,	,, ,,	(2,079).
Coleoptera - - -	990;	,, 30 %	,,	,, ,,	(3,227).



LOCALITIES FOR HYMENOPTERA-ACULEATA IN LANC. AND CHES.
HAWKESHEAD
(Lancaster)
BLACKPOOL
WHALLEY
(Preston)
R. RIBBLE
SOUTHPORT
RIVINGTON
BOLTON
ROCHDALE
PENNINE CHAIN
FORMBY
INCE BLUNDELL
CROSBY
WATERLOO
KNOWSLEY
SIMMONSWOOD MOSS
KNOTTY ASH
LIVERPOOL
RAINHILL
HALSNEAD
HALEWOOD
ROCK FERRY
CHEETHAM HILL
CHAT MOSS
ECCLES
MANCHESTER
R. MERSEY
STALYBRIDGE
WARRINGTON
BARTON
STRETFORD
CHORLTON
WITHINGTON
ASHTON
DUNHAM
BOWDON
SALE
DIDSBURY
MARPLE
HAZLEGROVE
DISLEY
LINDOW
HIGH LEIGH
R. BOLLIN
MOTTRAM
HOYLAKE
WALLASEY
KIRBY
BIRKENHEAD
OXTON
THURSTASTON
BEBINGTON
HESWELL
BARNSTON
HOOTON
EASTHAM
R. MERSEY
R. DEE
WILLASTON
LEDSHAM
INCE
FRODSHAM
HELSBY
MANLEY
CUDDINGTON
DELAMERE FOREST
UPTON
BACHE HALL
CHESTER
ALDFORD
NORTH WALES
MALPAS